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NOTES ON GAUSS AND HIS AMERICAN DESCENDANTS

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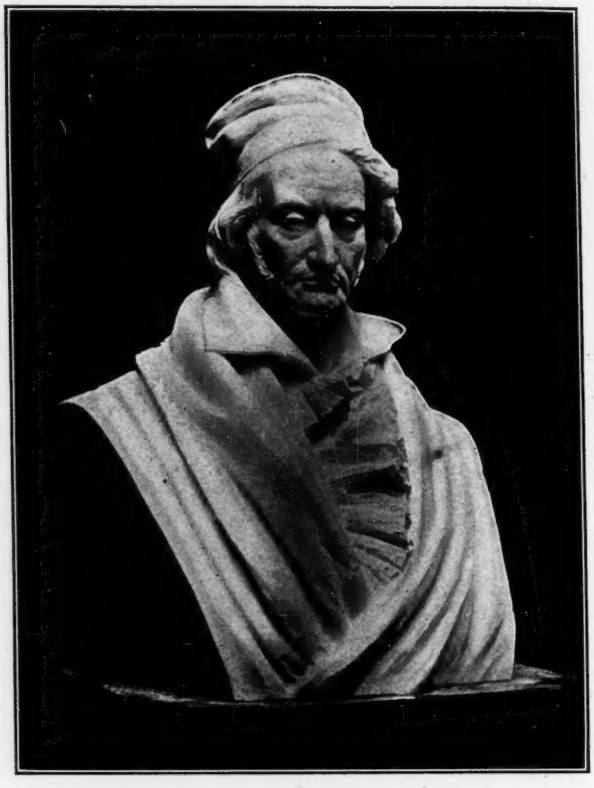
UPON the Hohehagen, the highest mountain summit in the vicinity of Göttingen, there was dedicated on the twenty-ninth of July, 1911, an observation tower which commands an imposing and picturesque view of the university town of Göttingen, as well as of the ruins of proud medieval castles upon the mountain ridges beyond. This observation tower on the Hohehagen, now becoming a favorite objective point for excursionists, bears the name of a great scientist who made Göttingen famous. It is called the "Gaussturm" or "Gauss tower." Rising to a height of 120 feet, it overlooks all surrounding trees and objects. Within this tower is a room, called the "Gausszimmer," the chief ornament of which is a large marble bust of the great scientist, designed by the sculptor Eberlein. Another interesting exhibit is a reproduction of the Gauss-Weber electro-magnetic telegraph. It is well known that Gauss and Weber in 1833 had a crude telegraphic line between the observatory and the physical laboratory in Göttingen, a distance of 9,000 feet. This was eleven years before Morse sent his message from Washington to Baltimore, "What hath God wrought." Gauss and Weber employed, in signaling, the deflection of a galvanometer needle moving to the right or left. Henry and Morse in this country produced signals by an electro-magnet attracting an armature. While the Morse instrument is widely used in land telegraphy, the galvanometer needle found early application in ocean telegraphy. Germany has always prided itself on the Gaussian telegraph. On the Potsdamer bridge in Berlin there is a statue representing Gauss in a sitting position, watching with keen interest the deflection of the needle of a telegraphic instrument before him. By his side there is a youthful allegorical figure stretching a telegraphic wire around the globe.



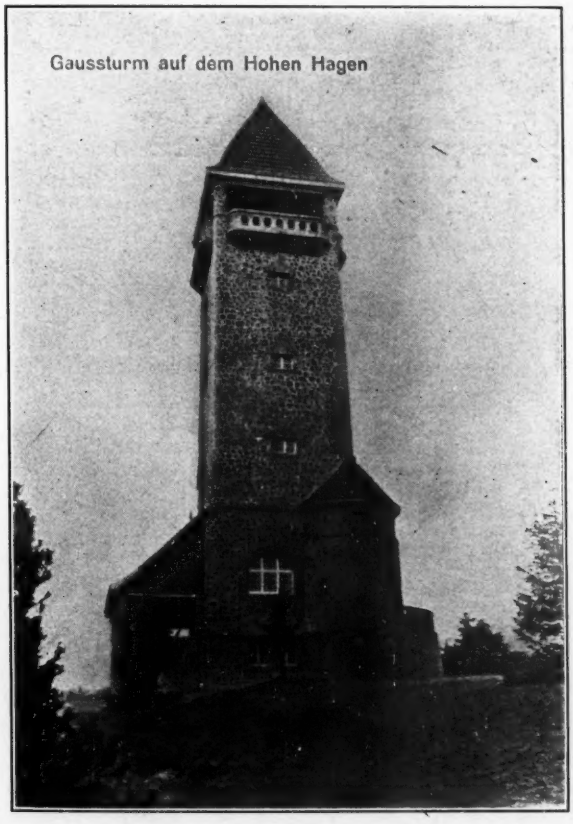
PROFESSOR EBERLEIN'S BUST OF C. F. GAUSS, RECENTLY PLACED IN THE GAUSS TOWER ON THE HOHEHAGEN.

The Gauss tower on the Hohehagen indicates the exact location of a corner of a geodetic triangle in a survey established by Gauss. This triangle is classic in the history of geodesy. It was on that survey that the now famous instrument, invented by Gauss, called the "heliotrope," was used for the first time. It reflects the rays of the sun from one station to another many miles distant so that directions can be measured accurately and signals sent from station to station.

The high esteem in which Gauss is held in Germany is shown also by the recent dedication of another "Gauss room" in the town of Braunschweig. The house at No. 30 Wilhelmsstrasse, bears a tablet with the inscription: "In this house was born Carl Friedrich Gauss on April 30, 1777." The plan to establish in this house a "Gauss-zimmer" was carried out by the Historical Union of the Herzogtum Braunschweig. All sorts of Gauss relics have been gathered and are exhibited here. Photographs are shown of near relatives and the immediate descendants of Gauss, among whom are several Americans. Braunschweig has always been proud of its illustrious son. There is a statue of him in that city, on one side of which the close observer will

notice a regular polygon. This geometric figure recalls Gauss's first mathematical research, the discovery of a method of inscribing a regular 17-sided polygon into a circle by means of a ruler and a pair of compasses. On the Gauss bridge in Braunschweig a bronze celestial globe exhibiting the planet Ceres reminds passers-by of another great achievement of Gauss. Among astronomers his name first became known through his determination of the elements of the orbit of this planet Ceres from the observations on it made in 1801 by Piazzi in Italy. These observations were such that its orbit could not well be calculated by the old methods, and it remained for the genius of Gauss to devise a method of computing elliptic orbits which was free from the assumption of a small eccentricity and inclination. With the aid of Gauss's data the new planet was rediscovered by Olbers in Germany. Later Gauss gave much attention to modes of computing planetary and cometary orbits.

At the observatory in Göttingen, where Gauss carried on his great researches, there has been arranged in the rooms formerly occupied by



THE GAUSS TOWER ON THE HOHEHAGEN, NEAR GÖTTINGEN, DEDICATED JULY 29, 1911.

him a Gauss archive, in which the manuscripts of Gauss and other interesting material have been deposited. In the town of Göttingen there is a statue of Gauss and his friend Weber, the physicist whom we have mentioned earlier. Gauss, in a sitting posture, and Weber, standing, appear engaged in a lively scientific discussion. Besides the telegraph, Gauss and Weber designed instruments which were used in the early determination of the magnetic elements of the earth's magnetism. Through Gauss's initiative there was established the German Magnetic

THE HOUSE IN THE CITY OF BRAUNSCHWEIG WHERE C. F. GAUSS WAS BORN AND WHERE GAUSS RELICS ARE NOW ON EXHIBITION

Union, with the object of securing systematic and continuous observations. Important as were Gauss's achievements in geodesy and the earth's magnetism, his chief scientific researches were in mathematics and astronomy. During his labors at Göttingen, extending over nearly half a century, he made profound researches in the theory of numbers, which is one of the most subtle branches of mathematics. He greatly enriched by his investigations the theory of imaginary numbers, the

theory of equations, the calculus of variations, the theory of probability, the geometry of surfaces, and the subject of infinite series. Like Sir Isaac Newton, he at times displayed a disinclination to enter upon a prompt publication of his scientific deductions. As a consequence of this, others rediscovered and published results which Gauss might have claimed for himself. Thus it is now known that some of the discoveries on elliptic functions made by Abel and Jacobi had been worked out by Gauss thirty years earlier but not published. According to Professor Felix Klein, some Gaussian manuscripts reveal a knowledge of the fundamental ideas of quaternions, a subject fully elaborated later by the genius of the Irish astronomer, Sir William Rowan Hamilton.[1] Perhaps the most striking case of loss of priority of discovery due to failure to place his results at the disposal of the general scientific public, is that of non-euclidean geometry. For many years Gauss permitted his mind to dwell upon the subtle subject of parallel lines, and he reached some exceedingly original results. But he did not write down in full what he had worked out in his mind, and nothing was published by him on this topic. Off and on he would touch upon this subject in letters to scientific friends. He expressed to them his intention not to allow any part of this research to reach the general public during his lifetime. On January 27, 1829, he wrote to Bessel: "Probably I shall not be ready for a long time yet, to prepare for publication my very extensive researches on this subject and perhaps this will not happen during my lifetime, for I would dread the clamor of the Bœotians, were I to speak out in full." Imagine his surprise when the Hungarian Wolfgang Bolyai, a close friend of his during their student days at the university, sent a printed document of twenty-six pages written by Wolfgang's son, John Bolyai, in which the young Bolyai had worked out with wonderful clearness and originality the fundamental propositions of non-euclidean geometry. Gauss saw at once that he had been anticipated. How did the world-renowned mathematician of Göttingen behave toward the young and unknown Hungarian? Students of scientific history know that on questions of priority of discovery many a bitter battle has been fought. Scientific men are only human, and they frequently fail to see the full merits of rival claimants. But Gauss showed himself as generous as a man as he was great as a scientist. After reading John Bolyai's published dissertation, he wrote to his friend Gerling as follows (February 14, 1832): "I consider this young geometer v. Bolyai a genius of the first rank." To his old friend Wolfgang Bolyai, Gauss wrote (March 6, 1832) in this manner:

[1] Professor P. G. Tait declared that Klein is mistaken and that the Gaussian restricted forms of linear and vector operators do not constitute an invention of quaternions. Klein's article is in *Math. Annalen*, LI., 1898. A note by Tait appeared in *Proc. of the Royal Soc. of Edinburgh*, December 18, 1899.

Now about the work of your son. If I begin by saying that I dare not praise it, you will doubtless be startled for a moment. But I can not do otherwise. To praise it would be to praise myself, for the entire contents of the paper, the path which your son has pursued and the results which he has reached agree almost throughout with my own meditations, entertained by me in part since 30–35 years. By this I am surprised to the highest degree. It was my intention, during my lifetime to publish nothing of my own work, of which but little has thus far been put down on paper. Most people do not have the proper appreciation of the subject in hand and I have found only a few people who

THE STATUE OF GAUSS ON THE POTSDAMER BRIDGE IN BERLIN.

receive with interest the things I tell them. To be able to do so, one must have felt vividly what has been wanting, and on this point most people are quite in the dark. But it was my intention, some time to write down everything, so that it would not eventually perish with me. I am greatly surprised that I am saved this trouble and it is most pleasing to me that it is the son of my old friend who has anticipated me in such a remarkable way.

Would that all men of science could show the generosity toward rivals in matters of priority that Gauss showed toward John Bolyai. Gauss recognized the genius of Bolyai, gave him full credit for what he had done and gave up his own plans of preparing a paper on the new geometry.

Gauss lived nearly half a century at Göttingen in the midst of continuous work. In 1828 he attended a meeting of scientists in Berlin. After that he never left the vicinity of Göttingen, except in 1854, when a railroad was opened between Göttingen and Hanover. In the letter of August 7, 1852, which we print below in full, Gauss refers to his intention of going to Hanover, when the railroad is completed, and he says that he has not passed a night away from his own fireside since 1830. In marked contrast to this love of seclusion is the "Wanderungslust" of two of his sons, Eugen and Wilhelm. We shall see that both of them made their homes in the United States. A letter written by Wilhelm to his father in March, 1835 (kindly shown me by Mr. William T. Gauss, of Colorado Springs, Colo., a son of Wilhelm) discloses an intense longing to make his home in America, which country made uncontrollable appeals to his imagination. Wilhelm was then twenty-two years old and away from home. Here are fragments from the long letter on this subject:

> Father, I pray you again, by every earthly consideration, let me come home and next fall or winter go to America! I have written you that I can secure a position at Potsdam. . . . If you command me to accept it, then of course I must obey, but I can not remain there permanently. I have no peace day or night and in everything I do, America stands before my eyes! . . . Let me come home and study the English language during the summer, let me make the necessary preparations, and start in September of this year by way of New Orleans for Missouri.

He remained in Germany two years longer, devoting himself mainly to the study of agriculture, in preparation for the life he expected to lead in America.

Gauss had four sons, one of whom died in infancy. We have already mentioned Eugen and Wilhelm. Joseph, the oldest, was an officer in the German army, later a director of the Hanoverian railroads. In the latter part of the 30's he visited this country as a representative of his government to investigate the American railway system, then in its infancy. He maintained his residence in Germany, where later he assisted his father in the triangulation of the kingdom of Hanover. He died in 1873. His son Carl August Gauss, of Hameln, is the only grandchild of the mathematician who is living in Germany to-day. The United States now claims most of the descendants of Gauss. He had two daughters, who were married, but had no children. The older, Minna, married Ewald, the orientalist.

It is conceded that Eugen inherited more of his father's genius than did his brothers. Eugen left for this country as a boy of nineteen. Before coming he had been attending the University of Göttingen. While he was not more reckless than other students, he spent some of his time in fighting duels, enjoying the society of boon companions, and in doing whatever else made up the gay, yet not dissipated, life of a

Göttingen student of those days. The accounts of Bismarck's career give a good idea of what this life was. Upon one occasion Eugen gave a dinner to some of his student friends. Instead of paying for the score himself, he sent the bill to his father. When his father rebuked him for this, he took violent offence. Without mentioning the matter to either of his parents, he made up his mind to leave home and go to the United States. A day or two after that incident he left for Bremen to take ship for New York. Upon learning of this, the father promptly did his utmost to induce Eugen to return home, and, when failing in his endeavor, offered him money for the journey. Eugen remained in New York until his money was spent. Then he enlisted in the army of the United States as a private soldier. He was transferred with other enlisted men to a post at St. Peters in Minnesota. He had been there but a short time, when the officers of the post discovered that he was an educated man and, desirous of relieving him of the more onerous duties, placed him in charge of a small library at the post. After having served five years in the army, Eugen entered the service of the American Fur Co. and for about four years spent most of his time at Fort Pierre in South Dakota. It was about this time that his brother Joseph Gauss came to the United States to examine American railways. He brought with him letters of introduction to General Scott and other prominent men. He wrote his brother, offering to use his influence to secure him a commission in the army. This offer Eugen declined, as he had other plans laid out for himself. Shortly after a visit in 1840 to his brother Wilhelm, who had by this time come to America, Eugen settled in St. Charles, Mo., where he engaged in business. In 1885 he removed to a farm near Columbia, Mo., where he died in 1896. Whatever estrangement may at first have existed between Eugen and his father on account of his departure from home against his father's will was not of long duration. One of the letters received by Eugen from his father in Göttingen was written shortly after Eugen informed him of his intention to marry. It was cordial and affectionate. The original of this letter is now in the Lick Observatory.[2]

The youngest son, Wilhelm, came to America in 1837, with the consent and approval of his father. He went on a sailing vessel to New Orleans and from there traveled up the Mississippi to Missouri. Just before leaving Germany, he had married Louisa Aletta Fallenstein, a niece on her mother's side to the mathematician Bessel. In the published Gauss-Bessel correspondence mention of the young couple is frequently made. In 1855 he located permanently in the city of St. Louis, where he was engaged in the wholesale mercantile business until the

[2] For a copy of this letter and for additional details relative to the life and intellectual qualities of Eugen Gauss, as well as information relating to other descendants of C. F. Gauss in America, see an article, "Carl Friedrich Gauss and his Children," in *Science*, N. S., Vol. IX., 1899, pp. 697–704.

year of his death, in 1879. He was recognized as one of the representative business men of St. Louis. He was a man of great warmth of heart and of fine intellectual gifts. It may be mentioned that, when he went to St. Louis to live, he brought home with him a family of his slaves, as house servants. Before the civil war he freed all of them, starting the father as a hack-driver on his own account, by giving him a pair of horses and a carriage. To be an independent hack-driver was the ambition of many a southern negro of that time.

At the present time there are three grandsons of Carl Friedrich Gauss living in Colorado, four living in Missouri, and one in California.

The following letter (hitherto unpublished and now in the possession of Mr. William T. Gauss, of Colorado Springs, Colo.), penned by the mathematician Gauss only three years before his death, is of interest, not only because of what he says of himself, but also because of the references to social conditions and to some of his scientific friends. It is dated August 7, 1852, and is written to his son Wilhelm.

Lieber Wilhelm.

Ich kann nicht unterlassen, Theresens Briefe auch einige Zeilen von mir beizufügen.

Dein Schreiben vom 16 Januar (empfangen 26 Februar) hat mir mehrern Beziehungen viele Freude gemacht, ganz vorzüglich aber deswegen, weil daraus hervorgeht, dass Du in allen Deinen Verhältnissen mit Deiner Lage zufrieden bist. Wie wenige Menschen in Deutschland—oder soll ich sagen in Europa—können von sich dasselbe sagen! Inzwischen kann ich nicht läugnen, dass ich mir doch von Eurer Lebensweise kein recht (be)anschauliches Bild machen kann. Manches dabei wird freilich wohl (unendlich viel mehr als in der alten Welt) in beständig fortschreitendem Wechsel begriffen und jetzt ganz anders sein als vor 14 Jahren. Reisebeschreibungen durch Nordamerika gehen selten so weit nach Westen und so schwebten für mich die dortigen Zustände wie in einem Nebel. So möchte ich z. B. gerne wissen, ob die cultivirten Grundbesitze dort noch sehr zerstreuet, oder schon enge an einander liegen, ob unter den Besitzern viele Deutsche, oder ob es grösstentheils nur geborne Amerikaner sind, welche letztere in ihrer treibenden Unruhe wie ich glaube gewöhnlich nicht gerne lange an einem Platze bleiben, ob unter Deinen Nachbarn manche sind, mit denen Du freundschaftlichen Verkehr unterhältst, ob von den vielen Auswürflingen der letztjährigen deutschen u. a. Revolutionen oder Aufstände sich auch welche bis in Eure Gegend verschlagen haben. Das Auswandern nach Amerika überhaupt scheint noch mit jedem Jahre zuzunehmen; auch aus Göttingen hat eine Anzahl ihren bevorstehenden Abgang im Wochenblatt angezeigt, meistens sind es so viel ich erfahren habe nichtsnutzige Subjecte.

Uber sonstige hiesige Verhältnisse wird Dir ohne Zweifel Therese ausführlicher schreiben. Ich selbst fühle mit jedem Jahre mehr allerlei Altersbeschwerden; doch habe ich in Betracht meiner Lebensjahre eigentlich kein Recht zu besonderer Klage. Zu den traurigsten Folgen eines hohen Alters gehört, dass immer mehrere unsrer frühern Freunde einer nach dem andern abscheiden. Schon Ende 1850 starb Schumacher. Am 14 Februar 1851 ganz unerwartet Goldschmidt, der noch den Abend vorher wohl und vergnügt bei mir gewesen war. Dieser Verlust hat mir lange viele Sorge gemacht, da mein eigner Gesundheitszustand mir wenig Theilnahme an den Beobachtungen in der Sternwarte erstattet. Ich habe jedoch für jetzt die Lücke recht gut wieder ersetzt, indem anstatt Eines Gehülfen jetzt

zwei (in Goldschm. Gehalt sich theilend) angestellt sind. Es sind ein Paar geschickte für das Beobachten eifrige junge Leute. Der eine davon (Dr. Westphal) hat schon das Glück gehabt (am 24 Julius) einen Kometen zuerst zu entdecken.

Meyerstein befindet sich wohl, und hat mich ersucht gelegentlich Dich von ihm zu grüssen. Eben so Dr. Ruete, der seit mehrern Jahren hier Professor u. besonders als Augenartzt sehr gesucht ist. Er wird aber Göttingen nachsten Michaelis verlassen, da er einen glänzenden Ruf nach Leipzig angenommen hat.

Die Aussicht, die Du mir machst, dass ich einmahl Lichtbilder von Deinen Kindern, oder einigen von ihnen (das jüngste wird wohl vorerst nicht so lange ruhig sitzen können) erhalten soll, erfreuet mich sehr. Einstweilen aber bitte ich Dich wenigstens die Geburtsjahre u. Tage aller Deiner Kinder mir zu schreiben. Ich weiss es bloss von dem letzten (1 Julius 1851) und dem Briefe Deiner lieben Frau an Theresen. Aus dem letztern sehe ich auch mit Bedauern, dass ein von meinem lieben ältesten Enkel an mich gerichteter Brief verloren gegangen sein muss, da ich einen solchen nicht erhalten habe. Wenn er in Deinen nächsten Brief einige Zeilen einlegen will, so soll es mich sehr freuen, und braucht er sich mit der Sprache gar nicht zu geniren, ich empfange sie eben so gerne wenn er english schreiben will.

An der Eisenbahn von Hannover nach Cassel wird recht thätig gearbeitet, auch in der unmittelbaren Nähe von Göttingen. Der Bahnhof wird vor das Gronerthor kommen nahe bei der Anatomie. Erlebe ich die Vollendung (hoffentlich in etwa 2 Jahr) so mache ich wohl auch noch einmahl eine Reise nach Hannover; meinen dortigen (3¼ jährigen) Enkel habe ich auch noch nicht gesehen. Seit Sept. 1830 habe ich keine einzige Nacht ausserhalb meiner vier Pfähle zugebracht.

Nun lebenwohl, mein lieber Sohn, mit Deiner ganzen Familie.

Stets Dein treuer Vater

C. F. GAUSS

GÖTTINGEN den 7 August
1852

In the early part of the last century, when Gauss was still a young man, comparatively little attention was given to the mathematical sciences in Germany. In the words of a German scientist (Stern): "Germany of that day could say with the lioness in Æsop's fable: 'I have given birth to but one, but that one is a lion.'" Later in the century Germany could boast of many sons who command the lion's share of merit and distinction. The more recent German veneration for men of science and for matters pertaining to scholarship found expression in the remark once made by the Duke of Cambridge to Alexander v. Humboldt: "One frequently hears adverse criticisms of Göttingen, but as long as we have our library and Gauss, we can afford to let the heathen rage." Humboldt made the memorable reply: "I agree to this, but I must ask your Highness to interchange the order of the treasures and to give first place to the first mathematician of our time, the great astronomer, the genial physicist."

RESEARCH IN MEDICINE[1]

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IV. Present-day Methods and Problems

THE important activities in scientific medicine at the present time may be said, without fear of contradiction, to be in the departments of (1) immunology,[2] (2) protozoology, (3) chemotherapy, (4) physiological chemistry, (5) experimental pharmacology and (6) experimental pathology. The methods and problems of these various phases of medicine it is my intention to discuss, some at length, others briefly, in the present lecture.

Immunology is the science which would explain and apply the mechanisms by means of which the animal body is enabled to resist disease. As has been shown, the efforts of bacteriologists until about 1890 were devoted almost entirely to the study of the etiology of the infectious diseases and to attempts to combat these by vaccination with attenuated viruses. Another phase of bacteriology was, however, already under way, and this, in the earlier nineties, not only yielded results of great practical importance, but opened a new and ever-widening field of investigation. This was the study of the mode of action of invading bacteria and their products, that is, of the process of infection and intoxication, and the mechanism by which the host combats the invasion and absorbs or cures such infection by overwhelming the foreign organism. One of the first results was the study of a group of soluble poisons, toxins—formed by certain bacteria and which it has been found are responsible not only for the symptoms which follow certain infections, but also for that effect on the cells of the host which stimulates the formation of the antibodies which we call antitoxins. Pasteur in his study of chicken-cholera had noticed that a bacteria-free filtrate of a culture of the specific microorganism of this disease could cause the symptoms produced by the bacilli themselves, but does not seem to have given much importance to the observation. Later (1888) two of his assistants, Roux and Yersin, found the same to be true of filtered cultures of the diphtheria bacillus. Later it was found that the tetanus bacillus and the bacillus (*B. botulismus*) of meat poisoning yielded similar soluble poisons.

[1] The Hitchcock lectures, delivered at the University of California, January 23–26, 1912.

[2] The use of this term is not perhaps above criticism, but its increasing use and need of some comprehensive word to cover the various activities represented by the term "studies in immunity," "serology" which in themselves are not adequate, are given as justification of its use.

Further study showed that the various bacterial toxins produce not only a fatal intoxication, but that each has its distinctive effect, as shown by symptoms or anatomical lesion, when injected into animals, thus demonstrating that the poison of each bacterium possessed a specific action. This led not only to a better understanding of the pathology of such diseases as diphtheria and tetanus, but eventually, and of far greater importance, to the discovery of curative and prophylactic sera, or as they are generally known, antitoxic sera. The first step in this direction was taken when Behring and Kitasato (1890) showed that animals could be immunized against weakened diphtheria toxin and that the serum of such animals is capable of protecting other animals against its intoxication, and, moreover, demonstrated that such a serum can be used to cure the toxic symptoms produced by the diphtheria bacillus. This curative power, furthermore, was found to be due not to an action on the bacteria, but to a neutralization of the toxin which the bacteria produced; also the serum was strictly specific, that is, the serum of an animal immunized against diphtheria toxin protects only against diphtheria; that prepared by the use of tetanus bacilli, only against tetanus. This led directly to the production by Behring and Knorr of diphtheria antitoxin for therapeutic purposes (1894) on a large scale and to a general awakening as to the possibilities of serum therapy. The great benefits of diphtheria antitoxin as a curative and prophylactic serum are known to all; since its general use, in 1896, a reduction of the death rate in diphtheria from 45 per cent. to 10 per cent. marks this therapeutic measure as one of the most brilliant discoveries of medicine and of the brilliant century in which this discovery occurred.

The success with diphtheria antitoxin aroused the hope that a general principle—that of the formation of antibodies for the toxins of all bacteria—had been established on the basis of which it would be possible to develop curative sera for all infections. This expectation—on account of the simple fact that most bacteria do not produce soluble poisons—has not been fulfilled; but the impetus which the principle of serumtherapy gave to investigation has led to activity of great and permanent value, and to the development of a new science, immunology or serology, as it is variously called, which attempts to establish laws for the conditions which determine natural resistance to infectious diseases and the factors which increase or diminish this resistance. I approach this subject with hesitation, for the many difficulties it offers can not readily be overcome in a short presentation such as this must be. A few brief statements, stripped of the less familiar terms may, however, serve to elucidate the main lines of investigation.

All immunological studies are based on the known fact of the reinforcement of natural resistance to disease, as illustrated by serum

therapy in diphtheria and by vaccine therapy in anthrax. The attempts to elucidate the principles underlying these two methods have led to the development of many fruitful hypotheses and theories, and many diagnostic and curative procedures of great value. It was early evident that the explanation of resistance to infection, either natural or acquired, must be sought in the cells or fluids of the body and especially of the blood. Metschnikoff (1884) was the first to show the importance of the white cells of the blood in combating infection through their power of engulfing and dissolving bacteria, and his pupils have supported his views, both as to the direct and indirect influence of these cells, the leucocytes, in the production of immunity. On the other hand, since Nuttall, in 1888, demonstrated the bactericidal power of the fluids of the body, and particularly of the blood serum, the relation of the body fluids to infection and immunity has been incessantly studied. As a result, schools have arisen, some supporting the cellular theory and others the humoral theory, and still others combining both theories in the attempt to reach an adequate explanation of the process of immunity. With these schools are associated most prominently the names of Metschnikoff, Ehrlich and Bordet.

One of the earliest and most important observations, after the discovery of antitoxins, was that of Pfeiffer (1894). This was the demonstration that a guinea-pig, into which has been injected the spirillum of cholera, develops in its body-fluids a substance capable of dissolving the cholera spirillum. This bacteriolytic substance is specific, that is, it destroys only the cholera spirillum; and Pfeiffer and his followers, pushing their investigations further, found that this principle of a specific lytic body could be applied to other bacteria and to foreign animal cells as well. Its development led to great advances in the theory of immunity, to the development of the fruitful hypothesis known by Ehrlich's name, and to the production of antibacterial sera, *e. g.*, antistreptococcus serum, as contrasted with antitoxic sera.

Likewise, it was discovered that the serum of animals receiving injections of a given bacterium had the power to agglutinate this organism; and moreover that this principle held good for the blood serum in certain diseases of man. Upon these observations was based (1896) the serum (Widal) reaction for typhoid fever, a definitely specific and reliable diagnostic method which has been followed by many other valuable tests based on the same principle and grouped under the general head of serum diagnosis.

At the same time older procedures were not forgotten, as is shown by Haffkine's extension of Pasteur's principle of vaccination to include protective vaccination against cholera (1893) and plague (1896) and more recently Wright's application of it to typhoid fever. Thus the last decade of the nineteenth century is marked by the birth of both serum-

therapeutics and serum-diagnosis and by the extension of the idea of preventive inoculation. As may readily be seen, the fundamental observations of Pasteur, of Behring and of Pfeiffer had been elaborated into some of the most serviceable principles, acknowledged at the moment, in the science and practise of medicine. Nor is this influence a matter of the past. In our own day has been established the theory of specific precipitation of foreign proteins (Uhlenhuth, 1901). This has led to the elaboration of a specific test for the differentiation of both vegetable and animal proteins, a method which has been adopted for the determination of species, not only in bacteriology, but also as a medico-legal test for determining the origin of blood stains and as a general biological procedure.

So also, through the work of Denys and later of A. E. Wright, a body has been recognized in the serum which had the power to prepare bacteria for ingestion and digestion by the leucocyte. To this body the name of opsonin or tropin has been given. You will remember that Metchnikoff discovered the fact that the white cells of the blood have the power to engulf bacteria, Wright supplemented this conception of demonstrating that a substance in the serum could so affect bacteria that they would be taken up more readily and in greater numbers; also he demonstrated that this opsonic power of the serum could be increased, and as the results of his teachings a definite opsonic therapy has developed. This treatment depends on the principle of vaccination with bacterial products. Before Wright, with the exception of Pasteur's treatment for hydrophobia, vaccination was used as a preventive measure only, but the studies which his observations have stimulated have led to very satisfactory results in the treatment of certain local infections as those due to the pus cocci and colon bacillus. Also, these studies have extended the practise of immunizing vaccination, as a prophylactic measure with, it has been claimed, most favorable results in the prevention of typhoid fever. For example the sanitary record of the maneuver division of the United States Army recently stationed on the Mexican border shows that in a body of 8,097 enlisted men, careful sanitation and antityphoid inoculation prevented almost entirely the occurrence of typhoid fever; only one case of typhoid fever was observed, and it was not fatal; while at the same time in the near-by city of San Antonio 49 cases were reported. Comparing the record of the maneuver division with that of a division of the Seventh Army Corps stationed at Jacksonville, under quite similar circumstances in 1898, we have one case of typhoid among the 8,097 men of the former and 2,693 undoubted cases among the 10,759 men of the latter division. It must be admitted in regard to this record of the maneuver division, that it is difficult to say to what extent the excellent showing was due to careful sanitation and to what extent to the antityphoid inoculation,

but past experience with troops in camp would indicate that inoculation was an important factor at San Antonio. The question of the value of preventive inoculation is, however, still an open one. So also are other applications of the principles of immunity, as the production of anti-sera for snake-venom, and for the irritant (and perhaps intoxicating) vegetable agent causing hay fever.

I have earlier in this lecture referred to methods of serum diagnosis depending on agglutination or solution of bacteria or on the precipitation of protein. Immunology has recently contributed to medicine another diagnostic method of great value. Its principle is that of complement fixation, the theory of which is too complicated for brief explanation, but the method as applied to syphilis, in the well-known Wassermann test, has since 1906 occupied a most prominent position in the diagnosis and treatment of this disease, and is now accepted as a method of great value in the more obscure cases, and numerous attempts are being made to apply the principle to other diseases.

Another phase of immunological study is that of anaphylaxis, a subject concerning which the professor of pathology in this university is one of the best known authorities. Anaphylaxis, the condition of increased susceptibility dependent on the sensitization of an organism to a foreign protein, is by no means thoroughly understood, but it has thrown light upon immunity from a new angle and has stimulated an enormous amount of investigation. Its utilization in the detection of specific proteins, its apparent explanation of the tuberculin, mallein and similar reactions, the light it has thrown on serum sickness, so-called, and the possibility it offers of explaining diseases characterized by critical phases, have attracted a host of investigators, who see in it the key to many little understood phenomena of disease. As yet the practical results are meager, but the ultimate outcome promises much for medicine.

Another field, and one in which American investigations have been of the greatest importance, is the study of diseases the etiology of which is unknown, but which, it has been supposed, are in some instances due to filtrable or ultramicroscopic viruses. The recent work on poliomyelitis by Flexner and his associates is an example. This disease, appearing irregularly in sporadic and epidemic form, was in the past not definitely grouped among the infectious diseases. All attempts to find a causative microorganism have failed. The workers of the Rockefeller Institute and also certain European investigators have shown that the tissues of the central nervous system contain the virus, and that when the fluids of such tissues are injected into monkeys, typical poliomyelitis results. Moreover, the experimental evidence points to an elimination of the virus through the upper respiratory passages, thus offering a substantial basis for scientific prophylaxis through the proper care of the secretions of the nose and throat. Such investigations show how im-

portant the methods of immunology are, for here we have a disease which, as the result of the application of such methods, is definitely placed among the transmissible diseases and is given a satisfactory theory for prophylaxis in spite of an utter absence of knowledge concerning its causal agent. An analogy is seen in yellow fever, the microorganism causing which we do not know and for which we have no specific treatment, but which is controlled simply through our knowledge of its transmission by the mosquito.

While on the subject of Flexner and his work mention must be made of the most important contribution in recent years to our list of curative sera, the antimeningococcus serum. The production of this serum, which in the best form is the result of the labors of Flexner and his associates, is an accomplishment which, in reducing enormously the mortality of epidemic meningitis, is in itself a sufficient justification for the establishment of the Rockefeller Institute. The beneficial results of its use are very definite and the mode of its administration, by direct injection into the spinal canal, has been of great value in emphasizing the importance of the local treatment of localized infections.

Many other phases of activity in the field of immunity might be presented, but this brief and disconnected summary will, I hope, suffice to indicate something of actual accomplishment in this field, the main lines of present endeavor, and the many opportunities for future achievement. Much of present-day effort may not lead immediately to tangible results—an outcome not uncommon in medical research—but the volume of work in progress and the vigor with which it is being prosecuted promises ultimately the solution of the many problems of the infectious diseases.

The Investigation of Cancer.—In no field of medical science has the modern experimental method given greater results in a few brief years and offered greater promise for the future than in the study of that fatal and obscure disease, cancer. Owing to the brilliant initiative of Jensen in Denmark and Leo Loeb in this country, it has been shown that a form of cancer occurs in certain lower animals, particularly in rats and mice, that can be artificially transmitted from one animal to another of the same species. This fact has afforded a means of studying in detail the method by which a malignant tumor grows in the body and more particularly has thrown light on the resistance or immunity to tumor growth which may occur naturally in certain individuals and which may even be artificially produced. Scattered over the world are small groups of individuals, more particularly in England, in Germany and in America, who are devoting their entire energies to the solution of this problem. From several divergent sources have come published results of experiments which offer the greatest promise that we may soon learn a method of curing these tumors. Already Ehrlich

and Wassermann have shown the possibility of preparing specific cellular poisons for cancer analogous to those used in curing protozoan diseases. The final clue which will unravel the mystery of this complex disease would not appear to be as yet fully in hand, and yet I think no one of those most conversant with the problem would be surprised to find to-morrow that it has been discovered and that cancer was curable.

Protozoology.—It is of interest that about the year 1890, when bacteriologists ceased to announce discoveries with their accustomed regularity, owing to the fact that all readily recognized pathologenic bacteria had been discovered, the systematic study of protozoa began and some of the single-cell forms of life in the animal kingdom soon took a place as disease-producers alongside the corresponding form of the vegetable kingdom. Until this time, protozoa had been found in only two diseases of man, dysentery and malaria. In the year 1890 appeared the first books on the subject of protozoa as causes of disease, a small volume of one hundred pages by L. Pfeiffer, followed in the next year by Doflein's more extensive discussion of the same subject from the broader biological point of view. The bacteriologists of the preceding decade had by their efforts limited the number of diseases in which a bacterial etiology could be readily shown and it was natural, therefore, that the attention of investigators turned to the study of other microorganisms as factors in the production of disease. The careful technique of the bacteriologist had shown the methods to be used in the study of etiology, and, undoubtedly, the publications of Pfeiffer and Doflein stimulated general interest in the search for pathogenic protozoa. However this may be, it is a matter of record that in 1890 "only two human diseases were suspected of being caused by protozoa. . . . To-day more than fifteen are known or suspected to be of protozoan origin" (Calkins).

In the discussion of bacteriology I have referred to Leeuwenhoek as the first to see bacteria; he was likewise the first to see protozoa (1675). Two hundred years later, Bütschli (1875) offered conclusive evidence of the unicellular nature of these minute forms of animal life. In the intervening period, however, owing largely to the work of O. F. Muller (1786), Ehrenberg (1833–38) and Dujardin (1835–41), many forms had been removed from the "chaos animalculæ," the name under which Cuvier had classified them and their structure had been studied by Siebold (1845) and Max Schultze (1863). In this later period also several forms now familiar to us as occasional parasites of man had been described; as the *Trichomonas vaginalis* (Donné in 1837), the *Cercomonas hominis* (Davaine, 1857), the *Balantidium coli* (Malmsten, 1857) and the *Lamblia intestinalis* (Lambl, 1859).

The first parasitic protozoon, however, to be definitely associated

with a specific disease of man was the ameba discovered by Lambl (1860), first observed in the human intestine by Lösch in 1875, and said by the latter to be the cause of amebic dysentery. In 1891 Councilman and Lafleur, after a very accurate study of this disease, as it occurred in Baltimore, came to the conclusion that two types of amebæ must be recognized; one, the *Ameba coli,* was harmless, another, which they called *Ameba dysenteriæ,* they claimed to be the cause of tropical dysentery. In this view they were supported later by the feeding experiments of Casagrandi and Barbagallo (1897) and of Schaudinn (1903); the latter also introduced the name *Entameba histolytica* for the pathogenic form, and *Entameba coli* for the harmless form. It has since been found that two forms of tropical dysentery exist, one of which, as shown by Shiga, Kruse and Flexner, is due to bacteria—but equally definitely has the etiology of an amebic form been established.

In the meantime another protozoan disease was being investigated. Laveran, a French military physician, stationed in Algiers, announced in 1880 that the dancing pigmented bodies frequently seen in the red blood cells in malaria were altered hemoglobin granules within a protozoon to which he gave the name *Oscillaria malariæ.* This name was altered by Marchiafava and Celli to *Plasmodium malariæ,* in 1885, and Golgi, in 1886, by demonstrating that the characteristic paroxysms of the disease coincide with the segmentation or sporulation of this parasite, settled definitely the question of its etiologic relation to malaria.

The work on malaria constituted a very large part of the activity in medical investigation at this time. Until the middle of the nineties, many investigators were interesting themselves in the study of the different forms of parasites concerned, their life history and the methods for demonstrating them; these activities, with the study of similar parasites in birds, gave a great impetus to the study of pathogenic protozoa, and prepared many workers for a wider field.

Nevertheless, but few were prepared for the wonderful announcement by Smith and Kilbourne, in 1893, of the transmission of a protozoan disease through a blood-sucking insect. In this, the work of our own countrymen, on a malaria-like disease of cattle, Texas fever, the tick was shown to be the carrier of the *Pirosplasma bigeminum,* the organism responsible for the disease. The importance of this observation can not be over-estimated. It was the finger-post indicating the way to progress in the study of the transmission, and therefore of the prevention, of protozoan disease, and to Smith and Kilbourne belongs the credit of this great advance, which, it must be admitted, had a great influence on the study of the transmission of malaria and yellow fever. Many suggestions had been made from time to time that these diseases might be due to transmission by the mosquito; and these theories became indisputable fact when Ross announced from India in 1897–99

that the malaria of birds was transmitted by a species of mosquito (*Culex*) and when Grassi, Bignami and Bastianelli (1898–99) likewise demonstrated that malaria of man is transmitted by another species of mosquito (*Anopheles*). But before this, Bruce's study (1894–97) of the South African disease of cattle, which you may remember Livingston refers to as the "tse-tse fly disease," resulted in the discovery of the protozoan origin of the disease and the importance of the tse-tse fly (*Glossina morsitans*) in its transmission.

Soon followed (1900–01) the discovery by the United States Army Yellow Fever Commission—Reed, Carroll, Agramonte and Lazear—of the transmission of yellow fever by a third species of mosquito, the *Stegomyia,* and in 1903 Bruce announced that the sleeping sickness of Africa, due to a trypanosome, is transmitted by the tse-tse fly (*Glossina palpalis*). So also certain closely allied diseases of the far east, known as dum-dum fever, kala-azar, oriental sore, etc., were shown to be due to protozoa and to be probably transmitted by an insect.

The importance of these discoveries for prophylaxis was far reaching. It had long been known that malaria could be cured by quinine, but physicians in face of constant infections and reinfections were helpless. Now, the knowledge that the disease is transmitted by a mosquito, and by but one genus of mosquito, the *Anopheles,* allows the health officer to step in and by draining the breeding places of the mosquito to destroy the agent of transmission or, if this is impossible, to prevent contact with the mosquito by screens and other mechanical means. As far as we know, the parasite of malaria exists only in infected man and in infected mosquito. Perpetuation of the disease is due to the perpetuation of the cycle, man to mosquito, mosquito to man. If the parasite is destroyed in man or the *Anopheles* is not allowed to breed, the disease disappears. Not only has this been demonstrated experimentally, but it is in many communities a commonplace of sanitation.

Yellow fever is a disease, the causal agent of which is unknown, but so carefully has its prophylaxis been worked out on the basis of its transmission by the mosquito, as a result of the work of Read, Carroll, Lazear and Agramonte, that an epidemic of yellow fever would now be considered as due to ignorance or criminal carelessness on the part of those responsible for the public health. It is unnecessary for me to remind this audience of the heroism of Lazear and his associates and of the non-immune enlisted American soldiers, who offered themselves for experimental inoculation through the bite of mosquitoes infected with yellow fever. To their labors we, as a people, owe the present magnificent progress in the Canal Zone, the absence of yellow fever in the Gulf ports, an increase in human comfort and happiness and an increase in national prosperity and national progress; but still more, to

them, as also to Ricketts, who investigated Mexican typhus and succumbed to it, and to Walter Myers and Everett Dutton, of the Liverpool School, our science owes much in methods and in ideals.

Truly, no field of medicine offers so much of tragedy, of romance and of spectacular discovery as that of the pathogenic protozoa, and few offer such great difficulties. It is, however, one of the most promising fields of present-day effort and one which I would like to present more in detail. It must, however, suffice to end this presentation with mere mention of the successful cultivation of amebæ (Mesnil and Mouton), the cultivation of the trypanosomes (Novy and MacNeal), the discovery by Schaudinn and Hoffman of the spirochete, which we now know to be the cause of syphilis, and the finding of a very similar organism in yaws. Time might also be given to the various trypanosomes, to the spirochetes causing diseases of cattle and poultry and to the Negri bodies of rabies; also the discussion might be extended to include the broader field of tropical medicine, but instead, as it is the direct outcome of the study of protozoa, I must turn to a new phase of research in medicine, that known as chemotherapy.

Chemotherapy

As the study of protozoan diseases progressed it soon became evident that the method of combating such diseases must be different from that used against diseases due to bacteria. The chronicity of amebic dysentery and relapses in malaria indicated that the protozoan diseases are not self-limited and therefore not characterized by the development of immune bodies, similar to those of the acute bacterial diseases; also artificial cultivation failed to demonstrate that protozoa yielded bodies analogous to bacterial toxins, capable of producing, on injection, bodies with efficient antitoxic power. These and other facts precluded, therefore, a therapy based on the principles applied to bacterial vaccines or antitoxins.

The beneficial effect of quinine in the treatment of malaria and the cellucidal action of quinine on the ameba and other protozoan forms indicated that a therapy, to be successful, must be one in which a substance toxic for the protozoa in question is brought into direct contact with it. The establishment of such therapy and incidentally the creation of a new science, that of specific chemical therapeutics, has been the work, in the past seven years of Professor Ehrlich, of the Royal Prussian Institution for Experimental Therapeutics at Frankfurt. This new therapy is based on the principle that "a specific chemical affinity exists between specific living cells and specific chemical substances." This principle has always been the main theme of Ehrlich's work, as is seen in his application of the aniline dyes to the

study of the cells of the blood, his studies on vital staining and the selective action of methylene blue on the nervous system, the use of methylene blue in the study of the oxidations and reductions occurring in tissues, and his extensive studies in immunity. This experience, covering a period of twenty-five years, led Ehrlich to the belief that "for each specific parasite a specific curative drug must and could be found." And upon this assumption he began his experiments.

To appreciate thoroughly the difficulties of this task and the magnitude of the results, it must be understood that Ehrlich proposed a sterilization of the body in so far as the microorganism, against which the specific remedy was aimed, was concerned. The destruction of bacteria or protozoa outside the body by chemical means is a commonplace of surgical and public health measures; but the destruction of living microorganisms within the living body had never, until Ehrlich accomplished it, been possible without, at the same time, destroying also, in part or in *toto,* the cells of the host. To avoid the latter it was necessary, therefore, that the protozoa-destroying substance should have a specific chemical affinity for the protozoa in question, but little or no chemical affinity for the cells of the host.

It is impossible to give the details of Ehrlich's seven years of work on this problem; a brief description of the main results must suffice. The first work was done with trypanosomes, the mouse, which could be readily infected, being used as an experimental animal. After testing, with the aid of his assistant, K. Shiga, many hundreds of dye-stuffs, some old and some new, one, a member of the benzidin group, was found which retarded the progress of the trypanosome infection for several days. This led to a limitation of the experimentation to a study of the synthetic products of the benzidin group, many of which were made for the first time by Ehrlich and his assistants. The result was the discovery of a substance which exerted an actual curative effect upon trypanosomiasis. This substance, a red dye destroying trypanosomes, was given the name trypan red (trypan roth). If twenty-four hours after mice had been infected with the trypanosome of *Mal de Caderas,* a single injection of this dye was made, animals which ordinarily died in four to five days went on to permanent recovery. The blood, twenty-four hours after injection, was found to be free of trypanosomes, which indicated that the effect of the injection was to destroy absolutely every infecting protozoan. Thus was demonstrated for the first time the possibility of completely sterilizing the animal body by a chemical disinfectant without injury to the cells of the host.

In the course of this work an interesting observation was made. If, instead of a dose necessary to destroy all the trypanosomes, a slightly smaller dose was injected, the trypanosomes would disappear from the circulation for a short time and later reappear. If such

injection was repeated at intervals, the period of disappearance of the trypanosome would gradually shorten until finally the drug would have no effect on the infecting organism; in other words, a strain of trypanosomes had been developed which were resistant, immunized as it were, to trypan red and this resistance could be transmitted through many generations. Also, it was found that trypan red was a curative agent only for the infection in mice; on the trypanosome diseases of larger animals, as horses and cattle, it had no curative effect. However, the experience with trypan-red pointed the way to a solution of the difficulty; either a drug must be found which by a single injection would kill every parasite, or several different drugs must be used, which, acting on the same parasite, and thus allowing a combination treatment, would lead to a cure without the danger, to the host, of a single massive dose. It is impossible in the scope of these lectures to follow in detail Ehrlich's work or to go into the complicated chemistry of the substances used. It must suffice to say that as the work went on, Ehrlich and Weinberg found a substitution produced of trypan-red, amidotrypan-red, which destroyed the virulent parasite of nagana, the tse-tse fly disease, and that Mesnil and Nicolle, using the blue and violet azo-dyestuffs, prepared a trypan blue and trypan violet which caused the disappearance of the parasites of nagana, surra and mal de Caderas.

Another line of progress was through various combinations of anilin with arsenic. Before Ehrlich entered this field, Bruce had found arsenic to be a drug of value in treating the trypanosomiasis of horses (surra) and Thomas had found that atoxyl, a combination of arsenic and anilin, would cure a large percentage of infected animals. This latter substance had also been used in the treatment of the human disease, sleeping sickness. Ehrlich made a thorough study of arsenic compounds, and the result was the combination, arsenophenylglycin, a single dose of which absolutely and permanently cures all animals suffering from trypanosome infection.

At about this stage of the development of chemotherapy, Uhlenhuth and Salmon published an account of the brilliant use of atoxyl in the treatment of syphilis, which as we have mentioned, is due to a protozoan, the spirocheta pallida. Unfortunately, as atoxyl sometimes caused blindness, its use was not without danger and therefore not desirable. So Ehrlich immediately turned his attention to the protozoan diseases caused by spirilla, as chicken spirillosis, relapsing fever and syphilis. His labors on these diseases constitute one of the most fascinating of modern laboratory studies and his results are among the greatest of scientific discoveries. His intimate knowledge of the constitution of atoxyl and other arsenic preparations allowed him to proceed rapidly with "a great variety of substitutions, and innumerable arsenic derivatives were synthetized." As human syphilis could be

transmitted to the rabbit and relapsing fever to the mouse, the power of these preparations, as soon as manufactured, could be tested in the laboratory. The object, of course, was to find a substance which would kill the spirochetes without injury to the host. The result was the justly celebrated Ehrlich-Hata 606, chemically known as dioxydiamido-arsenobenzol, sometimes shortened to arsenobenzol, and, more recently, receiving the commercial name, Salvarsan. This substance in a single dose, 58 times smaller than the *dosis tolerata* (the largest dose which could be given with safety), cured definitely chicken spirillosis; a single small dose destroyed the spirolla of relapsing fever in infected mice, and a single injection of one seventh the *dosis tolerata,* caused the spirochete of syphilis to disappear completely from the experimental lesions of the rabbit within twenty-four hours. This last experience naturally aroused the hope of curing syphilis in man by a single injection given in the early stages. Such treatment, if successful, would supersede, or at least supplement, the empirical treatment by mercury which required a course of several years' treatment before a cure could be assured. The toxicity of the substance was, therefore, tested on dogs and then, to make sure it had no ill effects, on healthy men (assistants of Professor Alt), who volunteered for the purpose and finally the therapeutic effect was tried on relapsing fever in man. Iversen, of Russia, to whom this work was entrusted, found that one injection completely cured relapsing fever in 90 per cent. of his patients. Finally the substance was used in the treatment of syphilis in man. The completeness and rapidity of the curative action have been astounding. The effect on the lesions of the primary and secondary stages is to cause them to heal or disappear promptly; the spirochetes can not be found after a few days and the effect is apparently one of complete sterilization. Thousands of reports in the medical press confirm the general beneficial effect of this remedy and testify to the absence of ill-effects when properly administered. Even though further experience may modify the present optimism, nothing can detract from the magnificent service by which Ehrlich and his pupils have benefited humanity and added to the glory of medical science by establishing the principle of specific chemotherapy. With a record of about a dozen drugs[2] which can be used to cure or modify diseases caused by nearly a dozen different protozoa,[3] chemotherapy offers promise of results which, with serum-therapy and vaccination in bacterial diseases, will sharply limit the ravages of the transmissible diseases of man and animals.

[2] (I.) The arsenic group: arsenious acid, atoxyl, acetylatoxyl, arsenophenylglycin and dioxydiamidoarsenobenzol. (II.) Azo-dyestuffs: trypan-red, trypan-blue and trypan-violet. (III.) Basic triphenylmethan dyestuffs: parafuchsin, methyl-violet and pyronin.

[3] Nagana, surra, sleeping sickness, mal de Caderas, Texas fever, chicken spirillosis, relapsing fever and syphilis.

Here we must leave the story of the infectious diseases, which has occupied our attention from the beginning of the third lecture to this point, and turn to a brief discussion of other methods of modern research in medicine, those of physiological chemistry, pharmacology and experimental pathology, which had their beginnings in the subjects (chemistry, physiology and pathology) discussed in the second lecture. The presentation must, however, necessarily be but brief and fragmentary, a mere summary, in fact, of aims and methods.

Physiological Chemistry.—The beginnings in this most important field of research were in Liebig's exact methods[4] for the study of organic chemistry and Wöhler's studies which are famous on account of his synthesis of urea. It is usually stated that the cultivation of physiological chemistry as a distinct science, with independent institutes of its own, dates from the eighth decade of the past century, when Hoppe-Seyler in 1872 established his laboratory at Strassburg and in 1877 founded the *Zeitschrift f. physiologische Chemie.* But although this period does represent the first attempt to sharply separate laboratories of physiological chemistry from those of organic chemistry, on the one hand, and of physiology, on the other, the first independent chair of physiological chemistry was established as my colleague, Dr. John Marshall, informs[5] me, at the University of Tübingen in 1845 and was held by Eugen Schlossberger; likewise Schlossberger's laboratory was the first one to be devoted exclusively to the study of physiological chemistry. It was to this chair that Hoppe-Seyler was appointed in 1861, and which he held until shortly after the close of the Franco-Prussian war, when he accepted a similar chair in the University of Strassburg.

[4] These appeared in the following publications: "Instructions for the Chemical Analysis of Organic Bodies," 1837; "Chemistry in its Application to Agriculture and Physiology," 1840; "Animal Chemistry or Organic Chemistry in its Application to Physiology and Pathology," 1842; "Handbook of Organic Analysis," 1853. (Dates taken from early English translations.)

[5] Dr. Marshall's notes on the development of physiological chemistry at Tübingen are as follows: "In 1816 Dr. Med. George Kark Ludwig Sigwart at the request of the Medical faculty of the University of Tübingen delivered from time to time lectures on 'Zoochemie,' but notwithstanding that he was made professor extraordinarius in 1818 he was not provided with a laboratory. In 1835 the professor was given the use of quarters in the laboratory for agricultural and technical chemistry which was located in the old Tübingen castle. In 1845 Eugen Schlossberger, a pupil of Liebig and of Heinrich Rose was called to a professorship of physiological chemistry in Tübingen which was the first independent chair of physiological chemistry created at a German university and the laboratory was the first one to be established as a separate institution. From 1861 until 1872 this chair was held by Hoppe-Seyler when in 1872 he resigned to accept a professorship of the same title in the newly revived university at Strassburg. The laboratory in the old castle was occupied until 1885 when it was removed to the new building which had been erected for the subject."

Before and for some time after these events a great volume of work in physiological chemistry was done in laboratories of organic chemistry and of physiology; but the events at Tübingen and Strassburg served to concentrate attention on physiological chemistry and eventually to hasten the establishment of independent laboratories. For the first few years progress was slow; in 1882, to quote Dr. Marshall again, only two such independent laboratories, those of Tübingen and Strassburg, existed in Germany. In the intervening thirty years the situation has changed. Now, such laboratories exist wherever adequate teaching or intelligent research in medicine is attempted.

The early physiological chemistry was quite different from that with which we are familiar to-day. It was largely the analysis of the chemical composition of various body tissues and fluids. This early conception, however, soon gave way to a dynamic conception, the idea of function, and present-day investigators in physiological chemistry are concerned chiefly with the ways and means of cell action. The chemical constitution of the cell, its enzymes, the methods by which it builds up complex bodies from simple substances, or disintegrates a compound to its simplest constituents; in brief, the problems of digestion, metabolism and secretion in health and disease. These are the problems which concern this science and which, as its methods have been extended to include the study of the vegetable kingdom, as well as the lower forms of animal life, is now more frequently known by the broader term, biological chemistry. The dynamic point of view which to-day characterizes physiological chemistry is largely due to two influences which have come from the outside: (1) The study of intramolecular structure as carried out on the sugars, purins and proteins by the Fischer school, and (2) the study of the nature of chemical reactions, as taught by the modern school of physical chemistry, led by van't Hoff.

Its fundamental problems which during recent years have engaged the attention of its best workers and which still hold their attention are (1) the chemical composition of the protein molecule, (2) the part played by ferments or enzymes in the metabolic changes which occur within the cell and which are responsible for the functions of the various organs and tissues, (3) the general problems of nutrition and the relative values of different food-stuffs, (4) the question of the interrelation of function, that is, of the influence of the secretion of the cells of one organ or tissue on the cells of a remote organ or tissue, (5) the mechanism, from a chemical point of view, of natural and acquired resistance to disease and of phenomena associated with such resistance.

All of these investigations, it is seen, have for their object a better knowledge of the mechanism of cell activity.

Experimental Pharmacology or pharmaco-dynamics, as it is sometimes called, applies the methods of physiology and chemistry to the

study of the action of drugs, poisons and other substances which may alter normal function. Its early development corresponds to the period of the application of exact experimental methods to physiology which, as has been shown in an earlier lecture, dates from about 1840. Buchheim, professor of materia medica at Dorpat, established in his own house, in 1849, a laboratory for the study of pharmacological problems; somewhat later this laboratory became a part of the University of Dorpat and was, therefore, the first laboratory to procure for pharmacology, recognition as a science of university rank. Furthermore, Buchheim in 1876 in the *Archiv f. experimentelle Pathologie und Pharmakologie* (founded in 1873) defined the methods and aims which have guided pharmacological work for the past thirty-five years. He also made the first classification of drugs according to their physiological action.

The proper study of pharmacology is all-embracing. It includes not only the study of the mode of action of remedial agents in healthy individuals and the influence on such action of various abnormal or pathological conditions, but, also, the effect of a great variety of substances, as bacterial toxins, the secretions of venomous serpents and the products of metabolism, in short, all animal, vegetable or mineral substances in any way capable of altering normal physiology. Moreover, the study of the effect of these various substances is not limited to man and the higher animals, but includes the use of the lower invertebrate forms, bacteria and protozoa. It is, therefore, an all-inclusive branch of biology, dealing with the "comparative study of the action of chemical bodies on invertebrate and vertebrate animals." Its achievements are of interest to physiology, to which science it has contributed much, both in method and in fact; to chemistry, in that pharmacology has added largely to the data concerning the interaction of cell and chemical substance; and to practical therapeutics, in that it presents new remedies, explains the action of old remedies and defines the limitations of drug-therapy. Finally it has a definite relation to the general public welfare in that, by its methods, it establishes procedures for determining the potency of therapeutic remedies, thus preventing, on the one hand, ill effect from a drug of unusual power, and, on the other, guaranteeing a remedial agent of standard strength.

Experimental Pathology and Pathological Physiology are branches of pathology and physiology which, combining the methods of both these sciences with those of chemistry, attempt, by the study of abnormal conditions experimentally produced, to explain the disturbance in function consequent upon cell or tissue injury or disturbances in physiological or chemical equilibrium. Combining as they do the methods of several of the medical sciences, and having for their object the elucidation of definite problems in clinical medicine, they are essentially the

methods of a science of clinical medicine and have aided materially in the advance of this branch of medicine.

Such are the methods and problems of present-day research in medicine. The history of medicine teaches us that new methods and fruitful hypotheses may be brought forth at any time; new diseases, on the other hand, can now be expected only through changes in social relations and practises or as the result of new industries. Advance, therefore, would appear to lie in the concentrated application of present methods to present problems and in the application of such new methods, as may be confidently expected to appear from time to time, in any science which is so actively cultivated as is the science of modern medicine.

In this narrative of research medicine I have grouped the various phases of my presentation about men or events. These, as Hippocrates and Galen in antiquity; Vesalius and his influence on anatomy; Paré and his observations in surgery; Harvey, Hunter and Haller and their more or less isolated discoveries in physiology; Morgagni and his observations in pathological anatomy; and Jenner and his discovery of vaccination, represent the epoch-making efforts of workers widely separated and more or less isolated. In the early part of the nineteenth century, Johannes Müller, Liebig and Rokitansky founded respectively the sciences of physiology, organic chemistry and pathological anatomy upon the basis of concentrated laboratory effort and gave to these sciences an impetus the result of which we recognize to-day in the importance which they have attained. The main line of advance, however, has been in the past 70 years, and was made possible by the study of cells, through (1) the work of Schleiden on vegetable cells and of Schwann on animal cells thus establishing the cell doctrine; (2) the application of this theory by Virchow to pathology, and (3) Pasteur's conception of the rôle played by microscopic cells in fermentation and his application of this to the etiology of disease. Out of Pasteur's work grew, the treatment of bacterial diseases by vaccines and antitoxic sera, and the increased knowledge of infectious diseases gained by the study of bacteriology, led to the search for protozoa as causes of disease and the demonstration of the etiological importance of the latter, led, in turn, to the development of Ehrlich's chemotherapy as a means of combating protozoan disease. But while this was the main line of advance we have seen how Pasteur influenced surgery through Lister, and how anesthesia, through the efforts of Morton came also to aid this science. So, likewise, physiological chemistry came into being, indirectly as a result of Liebig's work, but more directly as a result of the needs of physiology for a better understanding of cell composition and enzyme action, and, finally, both physiology and physiological chemistry con-

tributed to the establishment of pharmacology and experimental pathology. Medicine, in the sense of internal medicine, benefited by each and every advance in each and every one of its contributary branches, and, through the application of the principles of physics and chemistry to methods of diagnosis, gained its present large equipment of instruments of precision and means of exact interpretation; surgery in like manner gained the X-ray and many technical and mechanical procedures; and preventive medicine, utilizing the knowledge obtained through bacteriology, protozoology, immunity and chemistry, shares, with the science of engineering, the glory of promoting in greater degree than all other factors the social and industrial welfare of humanity.

The facilities and opportunities possessed by American universities for the continuance of this progress will be the subject of the fifth lecture.

MODERN THOUGHT[1]

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WHILE purely metaphysical writings have not ceased to attract attention, it must be admitted that public interest has been drifting away from them and busying itself with inferences drawn from the study of nature and with speculations based upon these inferences. Yet here a philosophy has grown up, taking the form ordinarily of the theories more or less striking which leaders in scientific studies have held concerning the origin and laws of the universe. Some of these theories express very clear and decided opinions concerning man, his origin, capacity and destiny. But all agree that he stands in close relation to the visible, and that he alone of all living creatures can exercise a real and an intelligent control over it.

In a review of the thought of the last century, or century and a half, one is compelled to begin with a recognition of a fact which the majority of scientists, some of them unwillingly, accept, that back of all that appears, ever has appeared, or ever will appear, is thought, the outcome of mind, intelligent, directing, self-controlling mind. It is through the exercise of mental power that the meaning of nature is discerned, that significance is given to facts which penetration into her secrets has revealed. Neither atoms nor their combinations are of the least importance unless there is mind to make use of this combination. When we observe the changes which are constantly occurring in the natural world we can not avoid the question, What has thought to do with them? What influence have these changes had upon thought, what part has thought had in bringing them about?

Passing over for the present scientific theories formed and held in America, in southern or eastern Europe, and confining ourselves to the three great centers of modern European thought, France, Germany and Great Britain, we shall not be far out of the way if we assert that the beginnings of modern scientific theories are found in England or Scotland and have been made by individuals working in isolation with little help and scant encouragement from government, or royal societies,

[1] See review and statement of various forms of scientific thought presented and discussed with great ability by John Theodore Merz in his "History of European Thought in the Nineteenth Century," two volumes, William Blackwood and Sons, Edinburgh and London, 1905. This is one of the most valuable books of the time.

or universities: that these discoveries on British soil, like those involved in the theories of Newton, Harvey and Young, were taken up in Paris by members of the Academy of Sciences and through the aid of the government and by means of a wise organization of students of science were tested and their value made known to the world. It is to LaPlace of the Paris Academy of Sciences, more than to any one else, that Newton's theories were made known and were at last universally accepted. Paris up to the middle of the nineteenth century was the most important center of organized scientific study in the world. It was here that the experiments of Lavoisier in chemistry were made, here that Cuvier, Arago and scores of other men introduced into their studies the methods of exact measurements and weights, brought scientific procedure to mathematical precision and stated results in mathematical formulæ. It was in Germany, in the universities rather than in the academies, that these results were recorded, and through numerous periodicals given to the world. Germany long has been, and still is, the country of year books in which the history and progress of each special science is carefully traced and preserved for the benefit of the scholar. In France pains were taken with the literary form in which scientific discoveries were published, and a popularity was thereby secured for them unknown either in England or in Germany.

Two factors enter into intellectual progress, the extension or increase of knowledge, and its condensation. Reports of discoveries in any department of learning must be reduced to their lowest terms, or they will not be read, much less studied and made of use. In its accumulations of knowledge the nineteenth century is unsurpassed, but in condensation of knowledge some think it inferior to the time of Pericles in Athens. Nor is it certain, others say, that during the Renaissance, Italy did not surpass anything done in our modern era, and many give the palm to France during the sixteenth and seventeenth centuries. But the nineteenth century has no rival in its success in discovering and marking out new and better methods than any previously known, for increasing knowledge. It was in that century that the important conception of the unity of knowledge became prominent. In the opening of the twentieth century the desire to discover truth has not lost in strength, but our students and thinkers are exceedingly careful in the examination of the criteria of truth, for they have learned that not all which seems true, or is proclaimed as true, is true and can be accepted as true. Still men of science are wont to speak of their methods of study as "exact," and to call their discoveries "exact truth." The truths involved in these discoveries are tested by being brought into contact with practical life, that is, tested by experience. In all this thought is present and prominent. It is the thinker in the laboratory, in the factory, in the new industry established as the outcome of years

of experiment, who is to be considered, the thinker whose aims and works give character to the age.

Attempts have been made from time to time by men who have felt themselves masters of the thought and learning of their era to bring these results together and unify them under some comprehensive term. Thus Herder in his "Ideas for the History of the Human Race" emphasizes Humanity as the proper subject of study, Humanity in the large all-embracing sense. To Hegel it was the *Geist,* or the spirit of an age which deserves attention. Lotze, a philosopher of great repute not long since deceased, believing that men are living in that sphere of the cosmos of which Humboldt wrote, directed the thought of his time to man as the chief figure of the universe, the microcosmus in the cosmos. Herbert Spencer, without denying the existence of the unknowable or the absolute, testified to his belief in the unity of all things by the prominence he gives in his writings to the social organism. This organism he admits may be, probably is, under the control of an intelligent power but of which we can, he thinks, have no trustworthy knowledge. In these efforts to find some single expression under which all knowledge may be grouped and estimated at its real value, the tendency of the age toward unity is seen. What is desired and sought for is some theory which may be characterized by a single term by means of which whatever is can be explained, or its meaning clearly set forth. Humboldt in the cosmos sought to describe and explain the striking features of the physical world from the standpoint of a philosophical traveler. Hegel wrote as an idealistic philosopher, as a descendant, though not a follower of Kant. Herder and Lotze were influenced by the poetry and the current philosophy of their time, while men like Du Bois Reymond, denying that they were under the influence of any guiding star, adopted as their motto Ignoramus, Ignorabimus, Dubetemus, Laboremus. Haeckel as a pronounced materialist is still trying to guess the meaning of the riddles of the universe. In his position he is valiantly and ably opposed by the spiritualist, Sir Oliver Lodge.

It is not easy to find a road which will take one through the diversified and often confused thought of a single age, or a race, to say nothing of the thought of all the ages. Here and there events are prominent enough to characterize a century, or several centuries. Such was the case in the history of the Hebrew people, the early centuries of the Christian church, the century in which the power of the Pope culminated, the age of the revival of learning, the era of the reformation, the period of the French revolution, the beginning of the still continuing tendency among the more intelligent nations toward self-government, the most successful example being our own republic. Yet as a thinking age the nineteenth century has no distinguishing title. If it had we might have been spared such philosophies as those of the

unconscious, or the unknowable, and many others whose life has been short. Still, careful investigation into the leading traits of past centuries often reveals the existence of at least one thinker, sometimes of several thinkers, whose ideas and accomplishments have given character and prominence to his century. Thus we have the century of Augustine, that of Scotus Erigena, that of Anselm, that of Thomas Aquinas, that of Lord Bacon, that of Rousseau and Voltaire, who in a time of comparative quiet really prepared the way for the strife and destruction of the revolution. Perhaps there are men now living, even if we do not recognize them, whose thought and deeds will in the distant future characterize our times.

It has been well said that thought runs from the exact mathematical form to the vaguest religious form, from demonstration to feeling, from knowledge to faith. By this it is not meant that faith does not lay hold of realities, but that its objects are not the objects which awaken and retain the interest of the man of science, or of the lover of exact thought. Philosophy occupies herself with the region which lies between that of science and that of faith. We have therefore three kinds of thought, scientific, philosophical, religious, or as Kant might express it, transcendental. These may be united in a mind sufficiently capacious, as they surely are in the divine mind, but of this union this is not the place to speak.

In Germany from 1800 to 1830, perhaps a little later, the chief interest was in philosophy, as well it might be when such men were living as Fichte, Schelling, Hegel and their illustrious pupils. In France it was in science, of which the results were set forth in books or reports whose literary form was well nigh perfect, when men like Arago, Cuvier and their associates in the Paris Academy of Sciences were in their prime. In England it was the influence of individual thinkers, appearing here and there, often unexpectedly. For a time the writings of Wordsworth, Coleridge, Southey, Shelley and later of Browning and Tennyson affected thought, as in Germany the writings of Schiller, Lessing and Goethe had done. In a certain sense, as Merz remarks, the century began and ended in a ferment of opinion. In England and Scotland Wordsworth, Coleridge and Burns are followed by Byron. In Germany Kant is followed by degenerate materialistic systems of philosophy which he would have abhorred, as well as by some that were idealistic which yet would not have won his approval. It will be observed that the destructive schools of philosophy introduce nothing that is entirely new to the thinking world. Yet the cultivated mind is seriously at work, so that as the century progresses new ideas are formulated and are proving themselves constructive in character. This the words employed indicate, *e. g.*, energy, its conservation or dissipation. The words, individualism, personality recall Lotze with

his theory of values, while phrases like Natural Selection and the doctrine of evolution recall Darwin and Spencer. Words and phrases alike point to a struggle for condensation of thought in terms so clear and simple that no one can mistake their meaning.

Inasmuch as science has become international and we no longer speak of it as French, English or German, but simply as science, something in which all seekers after truth have a common ownership, a few of those explanations of the universe may now be considered which "exact thought" has given. We may look first of all at the abstract views, four in number, which are ancient in their origin, mathematical in their form and are still ardently defended. These are what have been termed the astronomical view of the world, the atomic view, the kinetic view and the physical view. The latter is the explanation given by those who believe in energy as the underlying and directing cause of movements or changes in the universe.

The astronomical theory rests on the doctrine of gravitation and explains the phenomena of the world in which we live as well as the relation and movements of the heavenly bodies to each other by the assumption of its universal existence. Upon the principle that bodies attract each other directly as their mass, inversely as the square of their distance, Newton enunciated his law of falling bodies. Upon this same principle the tides were explained as well as the revolution of the earth on its own axis and round the sun, the rotation of the heavenly bodies around their axes and around the sun, their motion through space and the velocity of this motion. If gravitation is universally operative on the earth, why should it not be operative everywhere? Through aid of the calculus Newton was able to apply the law of gravitation with the utmost accuracy and by its application lay bare the secrets of the heavenly bodies.

Newton's principles were received more favorably in France than in England. Under the influence of Laplace and the Paris Academy of Sciences, in spite of the protest of a sceptic here and there these principles were, after thorough and somewhat bitter discussion, accepted as true in France, and in no long time in all Europe. On Newton's theory of gravity, the corpuscular explanation of light made its way in scientific circles. Light was believed to be a substance and its laws of reflection and refraction were explained by the law of falling bodies.

The discovery of magnetism in 1791, of the voltaic pile in 1800, and researches into the phenomena of electricity, together with a growing conviction that space is empty and that matter is composed of atoms and requires a void, weakened confidence in the astronomical theory as a full and satisfactory explanation of all the phenomena of the universe. No one denied the facts which Newton had brought forward. No one ventured to assert that gravitation does not act everywhere, or that its

application does not explain cosmic phenomena, though difficulties even here were suggested, but even if it account for the action of molar objects, *i. e.*, those objects which can be weighed, measured and handled, it does not answer the questions which are put to us by the world of atoms. The study of chemistry and the queries raised by its revelations compelled the defenders of Newton's theories as a sufficient explanation of all phenomena in the heavens and on earth to enter upon a renewed investigation of the basis on which they rest, and to give patient consideration to the phenomena of the atomic world. At length, and because some other action than that of gravity was needed to explain molecular phenomena, the relation of atoms to each other, the phenomena of magnetism and electricity, what is known as the atomic theory was suggested and very generally received, not, however, as setting aside any truths discovered by Newton or involved in the astronomical theory, but as supplementing it and accounting with something like reason for the molar and molecular phenomena which it overlooked or did not recognize as existing.

This atomic theory is not an entirely modern theory. Empedocles of Sicily, who lived in the fifth century before Christ, accepting four primal elements, earth, air, fire and water, explained their modifications and their actions one upon the other, by assuming the existence of two principles, love and hate, attraction and repulsion, which are constantly in operation and which create the forms we behold and account for all the activity in the universe. The atomic theory developed, far more fully than by Empedocles, by Democritus of Abdera of the same century and defended by him with a wealth of learning possessed by no other man of his time gained wide acceptance. In its modern form the theory secured recognition in France and Germany earlier than in England. The exact methods of chemists and mathematicians, first in France then in Germany, led to the belief that matter is not a single piece of something in empty space, but is made up of a multitude of individual and indivisible particles which only partially fill this space, which is filled by that indefinable something which we call ether and which we affirm to be necessary both for sight and hearing.

As chemistry was more earnestly and wisely studied, as the laws of the combination of so-called elemental substances were better understood, men of science became less and less unwilling to admit the inadequacy of Newton's theory of gravitation as an explanation of all phenomena and the more ready to accept a theory which explained, as it seemed to them, the movements in the molecular world, and which, if matter is composed, as was asserted, of atoms, might explain conditions everywhere. Berzelius of Sweden demonstrated the truth of the theory by his wonderful experiments. Dalton's theory of atomic weights was accepted as in harmony with what seemed to be facts. Van't Hoff discovered, so it is believed, laws governing the arrangement of elements

or atoms in space which are as regular and as important as those assigned by the astronomers to the movements and arrangements of the heavenly bodies. If bodies are formed out of elements that combine with one another on some fixed and definite principle, and not under pressure of the law of gravitation, if this combination is universal, then there must be some law more elemental than that involved in gravity to explain this combination, to account for the phenomena of magnetism and electricity, to explain the disclosures of the microscope in that molecular world which underlies all that the most delicate instruments can render visible. For these and similar reasons the atomic theory of the universe has been proposed. Yet it is recognized as exceedingly complicated and not without need of modification.

But while this theory is held by large numbers of eminent scientists, since 1860 the study of gases has brought about a modification of it and given birth to the kinetic theory of the universe—the old theory of Heraclitus of Ephesus adapted to modern conditions—viz., that all things are in motion. The experiments of Clausius of Zürich, of James Clerk Maxwell of Scotland, and the practical applications of their theories and his own by Joule of Manchester in the study of heat, made it clear that what seems to be the dead pressure of the gases is an apparent rest of particles which are in reality engaged in a constant and law-determined bombardment of each other.

These particles, it was shown, move laterally and with well-nigh incredible speed. It is motion which reveals this long-hidden secret of the gases. It is motion also which accounts for the rigidity of solid bodies. The theory of motion, based on the doctrine of gravity as set forth by Newton and his successors, was the foundation of astronomy. That theory received the support of Huyghens of Holland, of Euler of Berlin and St. Petersburg, the famous mathematician, and was accepted by Young, Count Rumford and Fresnel. Young's undulatory theory of light was made known to the world during the decade from 1791 to 1801. The kinetic theory, the theory of motion everywhere, motion directed, determined and controlled by fixed law, received hesitatingly at first, was steadily opposed by Laplace, but was at last made popular by Arago and Fresnel in France. The doctrine of the polarization of light proved, it is affirmed, by the interference of light waves, contributed to its acceptance. Still opinions even in the Paris Academy were unsettled and confused. Hence the offer by the academy of a prize for an essay which should consider this whole subject, weigh calmly conflicting theories, discover the truth or the falsehood in each one of them, and with all possible thoroughness subject this new theory of motion to the severest tests. At the request of the academy, but against his wishes, Fresnel undertook the investigation. He began his studies with the conviction that this new theory had little foundation upon which to rest. But after careful experiment

and profound meditation he was convinced of its truth, and gave his reasons for his changed opinions in an essay which received the prize and was read to the academy in 1819, but which for some reason was not published till 1826. The difficulty in explaining transverse vibrations was overcome by showing that polarized rays of light have laterality, and by showing how a stretched string vibrates. The mechanical difference between light and sound was discovered. The tremor which causes sound, it was shown, is in the elastic fluid which carries the movement forward. Without motion there can be neither vision nor hearing. As motion is required to explain the behavior of gases and that fact had been set forth clearly in the experiments of Clausius, Maxwell and Joule, the conclusion did not seem to be far fetched that motion exists everywhere, and must be considered in whatever explanation one attempts to make of physical phenomena. It was also discovered that bodies moving rapidly round an axis, when immersed in water or in any movable medium, cease their rotation and flow forward as other bodies flow in water. In 1857 Helmholtz and Lord Kelvin brought forward the vortex theory to explain cosmic conditions and to account for the formation of the planetary worlds. The studies and experiments of Faraday in electricity and magnetism seemed to favor this new theory of motion. It was shown that the medium which carries light and sound can not possess the ordinary properties of a solid, a liquid or a gas. Hence a demand for a medium in which everything may exist, through the aid of which all movements or vibrations may be conveyed. Careful studies discovered the velocity which particles of hydrogen, for example, obtain, and Faraday pointed out lines of force, afterwards called "tubes of force" by Hertz, along which in a magnetic field, the electric movement passes. These movements were measured mathematically and with such care and accuracy that not only is the course which electricity takes known but its velocity also. But even if electricity be displacement, and its track be accurately discovered and followed, no one pretends to know just what is its innermost nature or denies that future study may entirely change present opinions as to its nature and its laws.

It has been proved, scientists declare, that all forces of matter may be measured and expressed in terms of *energy* or motion. During the last twenty years the conception has been formed that light is an electric or a magnetic phenomenon. Luminous waves are short rapidly moving waves and difference in color is caused by difference in length and frequency. But what is most important in this theory of motion is that it is not necessary, as in the gravitation theory or the atomic theory, to believe in the theory of action at a distance. Bodies move because other bodies press upon them. We see and hear because some sort of motion brings the ether into connection with eye and ear. The fact of gravity is not denied. Nor is it denied that Newton's dis-

coveries in reference to its action in the physical world explain the motions and relations of the heavenly bodies, but it is affirmed confidently that the theory of universal motion or the kinetic theory removes more difficulties in the explanation of the phenomena of the universe than either the astronomical or the atomic theory. In passing, it may be mentioned that this theory of universal motion was taught not only by Heraclitus, but by Anaxagoras of Athens, who saw that with his well-nigh innumerable germs he could not solve the problems of the universe apart from motion, and therefore introduced into his system of philosophy, the nous, or intelligence, to give the first push to matter and impart to it the movement which he believed to be universal and without which life could not exist.

The fourth of the abstract theories employed to explain the universe is the physical theory or the theory of energy. By this theory we understand that whatever is or has come to be has been caused by the force or energy there is in matter. The astronomical theory fails to account satisfactorily for molecular activity and chemical affinity: the kinetic theory is set aside because it is based on dualism or the existence of matter and ether. What is true in these theories is preserved and the difficulties found in the application of each one of them are avoided by the use of the general term energy, a term under which, according to Young, all that is known in science may be expressed. Energy or force is that something in nature which can do work and be stated in terms of horse power. We speak of latent energy, of energy created by friction, by the fall of water, by steam, and, although we are unable to define it, we describe it as something everywhere present and able, when properly harnessed or directed, to do a certain amount of work.

While refusing to speak of energy as a property of matter and denying that it is matter in any true sense of the word, it is affirmed that its amount in the material world can neither be increased nor diminished, that while from a heated object a certain portion of heat departs in cooling, a fact which is described as *entropy,* the sum total of energy, whether in the form of heat or of some other force, remains the same. This truth is set forth by Helmholtz as the conservation of force, a doctrine which, while admitting that a particular form of energy may be changed into another form, affirms that the energy itself is neither destroyed nor diminished by the transformations through which it may pass. Energy is valueless unless capable of transformation. It is good for nothing till it is made usable. Hence the study of energy has been more constantly directed toward discovering methods by means of which its power may be employed for the welfare of mankind, than toward ascertaining its nature. We know that energy may be changed in form, that it now appears as heat, now as light, now as electricity, now as magnetism. Nor are these the only

forms it assumes. Having taken pains to conserve energy or to obtain it, the practical question is how to use it?

That energy is everywhere present, underlies all things, was affirmed by Young, Rumford, Black, Müller, Mohr, Liebig, J. B. Mayer, Joule, Carnot, Sir William Thomson, or Lord Kelvin. It was through their efforts chiefly that the theory gained acceptance. It began to attract notice during the first third of the century, although its acceptance even now is by no means universal. Faraday, Mohr and not a few others believed in the existence of something indestructible, connected with matter, yet independent of it, but Helmholtz and his school explain everything mechanically. Heat, for example, is a product of motion. Other natural processes explain other natural manifestations. This theory was brought forward and defended in great part by the Scotch school to which belong the illustrious names of the Thomsons, James and William, Rankine, Clerk Maxwell, P. G. Tait and Balfour Stewart. Working alone, Clausius, of Zürich, reached substantially the same results. Maxwell studied the energy of the electric magnetic field, Joule the energy of the electric current, Watt measured heat. The idea of the unity of all chemical combinations was suggested by Arrhenius, of Sweden, in 1886, who showed how to decompose chemical solutions by the use of the galvanic current. Without saying anything more of this physical theory which presupposes the universal existence of energy as a force in matter, if not a constituent of it, as something which can neither be created nor destroyed by human agencies, though it may, through its power of convertibility into various forms of power, be made extremely useful, we simply add that energy may be so accurately measured by the aid of mathematics that before it is called forth from its hiding place we can ascertain exactly what amount of work it will do. Merz says that this theory has been useful to science in at least four ways.

It has brought out clearer definitions of terms.

It has caused a revision and recasting of physical and chemical knowledge.

It has criticized existing theories from a new point of view.

From this new point of view fresh departures in the study of science have been taken.

What energy is we do not know. It appears as intensity and power to do work. Is it a substance, material in its nature? What need then of ether to carry the undulations which produce sound or vision? Whatever the answer to these enquiries and many others which might be raised, energy seems to be a regulative and a directive rather than a constructive principle. Energy is found everywhere, but it nowhere appears as creative, save in bringing particles of matter together in new forms, or passing itself from one form of existence to another without growing less in amount.

From this brief review of the abstract or mathematical theories which have been proposed to explain the universe, it appears that while no one can deny the existence of gravity wherever there is matter, or of molecular activity or of motion, or of energy, it is certain that no one of them fully explains the mysteries of the universe. We feel the need of something more, some force or principle, some intelligence underlying all that we can see or discover as existing by the aid of the most powerful instruments, not only to direct and control forces already acting in and upon matter, but to create them and set them in motion.

Passing from these abstract explanations of the origin and nature of the universe and the consideration of their influence upon thought, four other theories, which may be called concrete from the fact that they rest on that which is visible and tangible, the morphological, the genetic, the vitalistic and the psycho-physical, require our attention. These theories are descriptive in their character and are based upon studies in the field rather than in the laboratory or the museum. Abstract science has been of immense advantage to the world of industry, and its methods of investigation will not soon be given up, but the progress made in the descriptive sciences has been very great and not without influence upon mind and life, or, as Merz is fond of saying, upon thought. The conception of energy and descent has helped to break down old distinctions and to establish on a firmer foundation the conception of unity in nature.

Morphology seeks to study objects as a whole rather than in detail, and to study these as they are in nature, before they suffer from changes wrought by the hands of men. The morphologist wants to know things as they are, and why they are. He recognizes the differences in the forms which substance assumes and in the structure of bodies. He considers their relation to each other and to their environment, the effect of climate and of time. But it is the object as a whole rather than any part of it in which he is interested. Such a method of study can not fail to be popular. It appeals to the people at large. Its descriptions can be easily understood and appreciated. Such men as Humboldt, Linnæus, Daubenton, Buffon and Cuvier have been among its distinguished advocates. Natural objects, it will be remembered, may be spoken of as cosmical, molar or molecular. Cosmical or heavenly bodies are magnitudes of immense size in space; molar objects are the objects we can see and handle here on the earth; molecular objects are the objects which are too small for our vision or touch to discover. Cosmical bodies are infinitely large, molecular infinitely small. If all bodies are similar in their composition, as the discoveries through the spectroscope seem to indicate, then a description of the nature of molar objects may be applied to those which are cosmic or molecular.

In the study of nature from a morphological point of view there is need of wide travel. Humboldt in his "Cosmos" has given us the re-

sults of investigations in portions of the world not often visited, and thus has made contributions of inestimable value to science. The study of animals in zoological gardens, if not in their native haunts, and of marine life by sea-going expeditions, or in extensive experimental stations by the seashore, as in Naples, Plymouth, England, or Woods Hole, Mass., has given a new impulse to the study of zoology and biology. The study of forms, especially those that are living, has been of great advantage to the physician also. From the days of Galen till the present time efforts have been made to apply the knowledge of physical laws to bodily healing. Galvanism, electricity, the nature and effect of different foods, the study of animal heat, have been made use of by the physician.

It is to Goethe that we are indebted for the word morphology, which describes his ideas as to the metamorphosis of plants. He saw, even if indistinctly, the unity of plant and animal life and the possible unity of all departments of nature. Merz says:

> In the perpetual variety of change the morphological view tries to define those recurring forms or types which present themselves again and again, towards which all changes seem to revert, thus bringing some order into what would otherwise be disorder and confusion. . . . The object of morphology as distinct from that of classification is the attempt to describe, and if possible to comprehend and explain the relative similarity as well as the graduated differences of form and structure which natural objects present to our gaze.

Natural objects can best be studied where nature presents them, under conditions which enable one to see them as they really exist in nature. But the study of nature, as a whole, is often best carried on by a study of its departments. Haüy creates for us in his mastery of the forms of crystals, and of the laws of crystallization, the science of crystallography. It is but a step from crystals to minerals and fossils, thence to plant and animal life. It is not surprising that, following hints from various sources and from his own studies, Theodore Schwann, having established the cellular theory of life, should assert, as he did in 1840, the essential identity of animal and vegetable structure. Since then his special department of study has made vast strides and ere long the science of biology may embrace everything in nature that relates even remotely to life.

Cuvier, the comparative anatomist, while cherishing large views, yet believed in types, in the fixity of species, and explained the changes produced in the world of animal life, the world of fossils, of plants and minerals, by sudden convulsions or catastrophes, by means of which old types of life are destroyed and new ones introduced. In this theory he was opposed by Étienne St. Hilaire, who explained the changes observable in the different departments of nature as the gradual outcome of the forces of nature. In this view he had the sympathy of Goethe.

Morphology without the microscope to assist in its study would have

made little progress. At the beginning of the last century it was in a backward condition. Improvements in the microscope and in the knowledge of its use, the studies of such men as Amici of Modena, Lister in England, the botanists Hugo von Mohl and Nägeli, of Stokes, Lord Rayleigh and Helmholtz, and the skill of Professor Ernst Abbe, of Jena, who has at his back the celebrated firm of Carl Zeiss, have rendered an exact study of cell life or formation of the tissues of all the processes and conditions of life possible and of value. But if the study of geology morphologically has produced men like Lyell, if in botany we have the great names of the Jussieus and De Candolle, in zoology, of Daubenton and Cuvier, more and more clearly has it been seen that nature is after all a unit in her processes. In the new field of astrophysics in which so much use is made of the spectroscope there is hardly a science known which is not employed in its development.

Yet the morphological study of nature alone could not long be satisfying. The progress made in the study of biology, the publication of Darwin's "Origin of Species" and Herbert Spencer's suggestion of the "physiological unit," called attention away from the forms of natural objects, from their study as individuals or collectively, or in relation to each other, from their distribution in various parts of the earth, to the changes wrought in them through the lapse of time, or by water, fire or convulsions of nature, to the processes of their formation or growth. Thus their genesis becomes of even greater interest than their form or their distribution. Indeed even the morphologist feels that his method of interpreting nature would be more satisfactory if he were fully acquainted with the methods which nature employs in the introduction and support of life.

This theory, the second of those we are now considering, is known as the genetic theory—and so called from its dealing with life. This theory assumes that all things are in motion and are developing along many lines, yet after some real order, if not after a fixed and definite plan. The word *evolution,* so generally used in England to indicate this process, is not universally employed in France or Germany. Herbert Spencer has the credit and the responsibility of introducing the word evolution into English-speaking scientific circles and also for using the word *genesis* to set forth a purely mechanical conception of the universe.

What we desire to know and seek to know is, How have things come to be, what they are and what is their history in time? Leibniz in his tract "Protogaea," published in 1749 called attention to the part fire and water have had, as indicated by visible proofs of their action, in forming the surface of the earth. He suggested a thorough study of many localities in order that general and satisfactory conclusions might be reached. Kant, influenced as he admits by the theories of Thomas Wright, of Durham, as to the formation of the planetary system, pro-

posed a theory of the formation of the universe which was afterwards developed into that well-known nebular hypothesis which till within a few years has been almost universally accepted as a reasonable explanation of the genesis of the stellar world. This theory was strengthened by the study of paleontology in England, and of embryology in Germany. During the first half of the century it was thought by many that life repeats itself, comes and goes in well-defined circles, but this hypothesis was displaced in the second half of the century by a belief in the gradual development of all natural forces toward a certain end. Hence the introduction of the word evolution.

Hutton's opposition to the catastrophic theory in geology prepared the way for Lyell in England who was unwilling to accept the genetic theory without modification. Nor was he content to remain a morphologist. "The Vestiges of Creation," published in 1840, and written by Robert Chambers, of Edinburgh, favored the genetic theory and applied it to the cosmic molar and molecular phenomena. The book, valuable for its suggestions and for the discussions to which it gave rise, met with decided opposition in many circles on the ground of its materialistic views and its tendency to explain nature without any reference to the supernatural. For a similar reason the opinions of many German scientists were unacceptable in Great Britain.

Yet in spite of the weight which the names of Humboldt, Cuvier and Richard Owen carried, it became evident, about the middle of the nineteenth century, that the morphological theory alone would not satisfy the scientific world. Doubts began to be cherished as to the fixity and permanence of species. There was opposition to the catastrophic theories in geology. Sir Charles Lyell in his "Principles of Geology" suggests orderly development, though without breaking with the older theories. Herbert Spencer in his writings in the early fifties sees more clearly than most others the necessity of some such theory as that which was afterwards known as the theory of evolution, or the gradual development of all forms and all life out of a simple original substance. As early as 1759 C. T. Wulff, as a result of his studies on cellular structure and growth, had come to the conclusion that growth is by additions and gave the world his theory of epigenesis. His influence dates from the year 1812 and was made effective through the work of Schleiden, Schwann, Mohl and Pander, who led the way in the study of that scientific embryology of which Pander is accounted the founder. Through these studies and those of Haeckel, which came later, the essential identity of the cell in structure substance and growth in the vegetable and animal world, was established.

As Herbert Spencer had prepared the English mind for the views of Darwin, so Haeckel prepared the way for their favorable consideration in Germany and on the continent. The work of Lamarck and of Von Baer, of Königsberg and St. Petersburg, was also of importance. But

"The Origin of Species" with its principle of natural selection, its preservation of useful qualities, the influence of environment and heredity, gave the genetic theory strong support. The views presented by its illustrious author were set forth with such clearness and defended with such wealth of illustration as to make their rejection a matter of great difficulty. Even those who were most hostile recognized their importance as well as their revolutionary character. It was evident to nearly every scientific man that henceforth the world could not be explained upon morphological theories alone, and that some such principle as that of natural selection must be presupposed in order to explain the facts which in almost every department of scientific research were daily coming to light. Natural selection has been defined as "that process in life, automatic in its nature and action by which in the struggle for existence useful differences are preserved and those which are not useful are destroyed." It is under the operation of this principle Spencer believed, and sought to show, that species are formed and the various manifestations of life accounted for. Those who accepted Mr. Spencer's theories in full, with few exceptions, accounted for the origin and evolution of the universe on purely mechanical principles.

But the questions as to life itself, its nature and its origin, were not on this evolutionary theory fully answered. Granting that the lowest forms of life are connected with the cell, that life is manifested in its structure and through its growth, even on the assumption that matter and energy only exist, the question can not be pushed aside. Whence is the energy which brings life into matter, organizes it and imparts to it the power or ability under the laws of evolution to create, perfect and continue at pleasure, the forms in which it chooses to appear? Logically the genetic theory must explain the origin and continuance of life on mechanical principles alone. A theory in sharp contrast to the genetic or evolutionary theory, which for many minds reduces life to a mechanical process, is what Mr. Merz calls the vitalistic theory. This theory is becoming more and more prominent with the increasing interest in the study of biology. What life is, what is its origin, what are its processes, are questions to which as yet completely satisfactory answers have not been returned. Bichot (1771–1802) defined life as the "totality of functions which resist death," a definition which gives little information as to the nature of life, or its origin. Claude Bernard (1813–78) wrote "life is the struggle of living forces against the non-living." Since the publication of Darwin's book on "The Origin of Species," or more exactly since 1866, a tendency is to be noted which seeks to establish parallelisms between processes in organic and inorganic bodies. Lavoisier was one of the first to study life from a chemical point of view, and to explain respiration, nutrition and the generation of animal heat as a form of combustion. In

1783 he and Laplace reported the results of their investigations on the subject of life to the Paris Academy of Sciences, but had little to say about the nature of life itself. In 1839 the British Association requested Liebig to study the subject of biology, as it then existed, and report at a subsequent meeting all that was known about it. The report was thorough, valuable and gave great satisfaction, but shed no light on the origin and nature of life. Though a vitalist, Liebig gave less attention to the defence of this belief than to the applications of the principles of chemistry to economics, especially as related to agriculture. Here his efforts were epoch-making. John Müller, of Berlin, and the Weber brothers, of Leipzig, investigated the physical and mechanical processes of life, so far as they could trace them by careful experiment in the laboratory. Du Bois Reymond and Helmholtz were trained by Müller and were among his most distinguished pupils.

It was while seeking answers to questions which investigations as to the origin and nature of life were constantly presenting that Helmholtz and Meyer, in entire independence of each other, discovered the principle of the conservation of force or energy. In 1847 Helmholtz proved, as he thought beyond any reasonable doubt, that living forces are manifestations of a certain quantity of power to do work. The outcome of these studies and the publication of theories based upon them brought about a change, in Germany especially, in the opinions hitherto held as to the nature of the vital force or vital principle. Not a few were content to reduce life to a mechanical process and to deny any distinction between life and matter. Others sought to discover the life process and to make its development clearer by many different theories. The "potential energy" of Helmholtz, the cell formation theory of Schwann, set forth in 1839, and the theory of Max Verworn, of Jena, that life consists in the "metabolism of proteids" do not require the supposition of any principle or force apart from matter itself to account for life in any of the forms in which it has appeared. And yet these theories do not deny the possibility of the existence of a life principle. Neither does acceptance of the "physiological unit," as suggested by Mr. Herbert Spencer, prevent us from believing that life may be something quite different from this unit and independent of it even if it manifest itself in and through it. Accurately as these life processes, as they are termed, have been traced by the most capable experimenters in the world, the product of these experiments, however exactly it imitate that of nature differs from it *in toto*. The laboratory product may contain the same elements, and so far as can be seen, arranged in the same proportion, and yet be entirely unlike the product of nature. No chemist has yet learned how to arrange atoms of matter in a living organism and adapt that organism to an environment in any such way as to compete with nature or indeed to give to the product of the laboratory anything worthy of being called life.

Familiar as one may become with the processes of organization, science has not yet been able to develop life out of what appears to be dead matter. Nor has it yet been proved that life is ever spontaneously developed from dead matter. Something more than mechanical processes, or than the action of matter itself, is required for the production of life even in its simplest and most primitive form. It may come through the cell. The cell itself may be merely a bit of protoplasm. This protoplasm may be either a germ of life or of the body. One thing seems certain; life proceeds from life and is never produced by mechanical processes, however constant these may be after life has once appeared, or however necessary they may be after life has begun its career in matter.

As has been said, the study of biology is fascinating. It is likely to become more fascinating with renewed efforts to attack the problem of life in its secret fastnesses. There will always be some students of biology who will be content to assume the existence of life either as something which may reasonably be taken for granted, or as furnishing a problem which at present can not be solved. But there will be others who will feel that biology must remain an incomplete science so long as the origin and nature of life are unknown. Its study as yet is in the era of beginnings and, in spite of its apparently insoluble problems, is full of promise. For the problems of the science are interesting and worthy an attempted solution, even if it be found advisable to put aside all thought of a solution of the mystery of life itself.

The fourth of the concrete theories of the origin and nature of the universe is called by Merz the psychophysical theory. It presupposes the study of mind and matter as found in man, in their relation to one another. In this study we may proceed from within by introspection or speculatively, or we may proceed from without objectively, obtaining our knowledge of mind from what it does, as shown in history, science, art, language, as Herder suggested should be done.

In the study of mind introspectively, or as it reveals itself in connection with the human machine of which it makes constant and necessary use, such men have been prominent as Cabanis, G. T. Fechner, the leaders of the Naturphilosophie school of Germany, Schelling, Hegel and others, the Weber Brothers, of Leipzig, Du Bois Reymond, Herbart, the philosopher who rejected physiology altogether and insisted upon the study of the mind as a unit by itself, Thomas Young, as shown by his theory of colors, Charles Bell, who discovered the difference between the anterior and posterior roots of the nerves of the spine and did not a little toward pointing out the difference in their functions, and John Müller with his "specific energies" which have long been taken for granted in all physiological reasoning as to the nature of sense perception.

Helmholtz, too, has contributed not a little to the solution of the

problem as to the relation of body and mind in his works on hearing and seeing and on vision and music. Lotze, who has the credit of having banished the idea of vital force from the study of biology, has given especial attention to the study of the methods or rules of the psychophysical machine. But the most prominent and successful investigator in this special department of mental and physical study is Professor Wundt, of Leipzig. It is said of him that he combines in the methods he follows the truth found in Lotze's medical psychology and Helmholtz's physiology of hearing and seeing with valuable additions of his own. He approaches the study of mind from the side of physiology, but is careful to take into consideration the whole problem of mentality and thus avoid theories founded on the study of only a part of it. The older metaphysical psychologists explained "the unity and unified totality of all inner and mental phenomena" by assuming the existence of an independent entity, "the soul, the person, the self," at the beginning of their discussions. This modern psychology is unwilling to do. The unity of the inner life and its unified totality is a clearly defined problem. This problem Professor Wundt has sought to solve. The question he puts to himself is, "Wherein consists the unity of consciousness, wherein is the totality of all mental life, individual and collective?" It will thus be seen that he and his school are leaving no difficulty untouched, and if the results of their studies are not universally accepted as satisfactory it will not be from any lack of thoroughness on the part of those who have made them.

Objectively, the study of mind psychophysically may be made a basis for the study of language. Or from the study of language one may form some opinion as to the nature and origin of mind. The problems of language are many and difficult of solution. How did language originate? How has it been developed? What does its use indicate? Broca in 1861 located the organ of speech in the center of the brain and by his writings laid the foundation of the science of phonetics, but was unable to overcome the well-nigh universal conviction that we can not account for the beginning of speech or of its development upon a merely mechanical and material basis. Speech implies thought, and thought has not been proved to be an attribute of matter or a product of mechanics. Wundt has not failed to study the problem of mental life objectively as well as introspectively. He has created the science of psychophysics. He has originated the theory of the parallelism of physical and psychophysical phenomena. As easily the first in this department of study, it is to his laboratory and to the men he has trained that students who are awaiting the solution of the difficulties connected with the psychophysical problem are turning for light. Wundt uses the word epiphenomena, which may be discontinuous, even if life itself is continuous, to explain various mental manifestations. But even here in the effort to explain centralization

and externalization, or the expansion and growth of mind, it would seem almost as if the existence of mind were assumed. At any rate, its existence is not absolutely denied or made identical with matter.

There are scientists who think of mind as they think of matter, and therefore study its operations as if it were the product of physical forces alone. They are not surprised at the conclusions of Cabanis that thought is a product of the brain as organized matter. These conclusions seem to them the logical outcome of Locke's theory of knowledge and of the philosophy taught by the Frenchmen Abbé Condillac and Helvetius. To them there seems to be no good reason why phrenology should not be able to locate the different powers of the brain, as Gall and Spurzheim tried to do at the beginning of the last century, even if no attempt were made to account for the existence of that something called mind which makes use of the brain.

However close we admit the relations to be between mind and matter, however fully we may believe in the influence of the physical upon the mental machine in man, it is well-nigh impossible to escape the conviction that mind and matter are diverse in their nature, that even if mind makes use of matter in its operations and is aided by it so that mind and matter may properly be studied together as a new science, they are not thereby made one and the same thing. There are many who still look upon physiology and psychology as different sciences, and while recognizing their close relationship and welcoming the results of studies and experiments in the border land between the two, they still feel as if there were a science of mind which demands other experiments and studies than those which physiology is able to furnish. Nevertheless, it is certain that in all future studies of mental philosophy the physical nature of man will be taken into account.

From this brief review of theories concerning the universe, its origin and meaning, each of which has been prominent in its turn, each of which indicates a different point of view on the part of its defenders, and each of which has in it a great deal of truth, it is clear that no one of them can now be accepted as completely satisfactory or as covering all the problems which meet us in trying to explain the universe. Taken together, they disclose and give a reason for many of the processes of nature, but they do not explain them all. Indeed, with every new discovery new vistas open, new questions arise, new difficulties are to be met. We may, therefore, content ourselves by accepting that as true which is proved to be true by all the theories. The fact of gravitation is undeniable, even if the astronomical theory is no longer received as adequate. Although no one has ever yet seen an atom, sound reasoning seems to require us to admit the existence of atoms and justifies us in appealing to mathematics to prescribe the laws of an atomic world. Nor can we deny the evidences of universal motion, or that the kinetic theory has a good basis upon which to stand. Equally evident is it

that force, or energy, energy that can be measured, harnessed, made to do work, exists in matter, and that no satisfactory account of nature can be given which overlooks or neglects it. In these abstract theories we proceed from small beginnings and build up our theories upon conclusions which seem to be true. The great names connected with them are Newton, Lagrange, Fresnel and Helmholtz. In the concrete theories objects are found ready made. We take them as they are and seek to describe them, and give a reason for their distribution and for their existence. Hence the theory which occupies itself with forms, or the morphological theory. Nor is it less a matter of interest to know how these forms have originated, out of what materials and under what conditions. Hence the genetic theory, which is supported by an array of names the scientific world delights to honor. With the study of biology, or life, it is natural that there should be a vitalistic theory, and that in process of time the student should discover a border land between mind and matter subject in part to physical, in part to mental laws. So we have the psychophysical theory of the universe, and the deep and growing interest in the study of its problems. Yet however true each of these theories is, and there is truth in them all, it is certain that as science enlarges her borders, opens new fields of knowledge, these theories will be given up, or be modified to such an extent as to be virtually new, that the study of nature and her processes will continue to the end of time and that whatever advantages the man of science may have one thousand or ten thousand years hence, the problems then demanding solution will be neither less numerous nor less difficult than those which confront him to-day.

Yet these studies are of great value, not only for the practical benefit they bring to the world, but for the influence they have on those who pursue them. They teach men to be tolerant, for the fields to be traversed are so wide, the subjects considered are so varied and complex, and are cultivated with such diverse aims, that one can not be surprised at the different conclusions to which investigators, equally in earnest and equally competent, arrive. In a scientific mind dogmatism has no place. Love for old truth does not prevent hospitality toward that which seems to be new. Scientific studies are fitted by their very nature to produce enlargement of mind, clearness of vision and devotion to the search after truth. The man of science is not only far better prepared for his studies to-day by the mental attitude he is compelled to assume in beginning his special work than ever before; the equipment at his disposal is more complete and better adapted to his wants than his predecessors have enjoyed. Indeed, he is in this respect the heir of all the ages. It is his own fault if he is irreverent toward old truth, inhospitable toward that which is new, or lacking in devotion to search after that truth with which nature is full and is waiting to reveal.

COLD STORAGE PROBLEMS

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COLD storage is but one of many methods of conserving foods. There is a period of plenty for every food substance, during which time much would go to waste if there were no provision for conservation, and when prices are low to the consumer and profits large to the producer. During the balance of the year food is scarce and must of necessity bring exorbitant prices, if within reach at all. Usually the period of plenty covers but a fraction of the year and bears to some extent a definite relation to climatic and soil conditions. The gap between the periods of plenty and scarcity is felt least in the centers of population, where transportation facilities make many foods available throughout the year. There, for instance, berries are obtainable before and after the natural period of supply has expired, the provisions being carried in refrigerator cars from southern and northern climates, where conditions favor their production. Also many fruits, such as oranges, grapefruit and pineapple, are carried successfully from tropic and subtropic countries to parts of the world where they can not be grown. These conditions are made possible by efficient transportation. Undoubtedly within the near future transportation facilities will be improved so as to encourage the raising of crops in tropical climates to such an extent that fruits and vegetables will be available in northern countries throughout the year. Many luxuries of the table could not now be obtained, were it not for the systematic conservation of food articles.

There are more than 3,000 million dollars worth of foods placed in cold storage annually, of which about one half is meat. Capitalists are expending money and scientists are giving their time to the exploitation of this promising field. Although the problem is still in its infancy, ways and means of furthering cold storage are being investigated. The chief problems to be investigated are the handling of foods previous to placing them in cold storage; the chemical changes taking place during storage; the study of the microorganisms that produce these changes; the sanitary conditions of cold storage warehouses, and the care of foods after leaving cold storage.

Many foods that constitute a regular and almost necessary part of the diet of civilized man are really nothing but the results of preserv-

ing perishable products. As milk, for instance, perishes within a short time, the nutritive constituents have been transformed for ages into cheese, butter, fermented beverages, etc. During recent years milk and eggs have been evaporated or desiccated. Their keeping qualities are thus enhanced and by adding the requisite amount of water they can be restored to nearly their original condition. Frozen milk, which, when thawed, represents milk almost equal to the fresh product, is being exported from Denmark in large amounts.

In a crude and empirical fashion many substances have been subjected to preserving agencies for ages. Savages have desiccated meat, or preserved it by immersion in sour milk. The farmer slaughters in the fall and keeps the meat in his cellar, where low temperature and the drying out of the outer layer protect the meat from serious decomposition. Fresh fodder for cattle is fermented into silage and grapes into wine. Acids for pickling vegetables, fruit and meat; sugar in concentrated solution for preserving berries and fruit; these means have long been utilized. High and low temperatures also have been used extensively for preservation with success. These methods have been reduced by science to certain fundamental principles, which may be considered conveniently under five heads: (1) Harmless preservatives. (2) Chemical preservatives. (3) Heat. (4) Desiccation. (5) Low temperatures.

These methods to prevent "spoiling" of foods were practised to some extent before the causes of food decomposition were understood. With the dawn of the science of bacteriology it was learned that decomposition of organic matter was due almost exclusively to the vital activities of microorganisms. It became clear that the sole end was the destruction or restraint of development of these minute organisms. Microorganisms require food, but this food must be diluted with water, consequently the abstraction of water by desiccation or freezing, or by boiling in concentrated sugar solutions will restrain their multiplication. Some chemicals are poisonous to bacteria, but are used only to a limited extent on account of possible injury to the consumer. High temperature kills microorganisms rapidly, low temperature slowly, and below the freezing point there is little, if any, multiplication. It must be distinctly understood that in the absence of microorganisms many years must elapse before organic matter can show any signs of decomposition. If this fact is borne in mind it will readily be understood that, if microorganisms are restrained from activity or destroyed, no matter by what means, there can be but little change in food substances. Antidiluvian animals have been disinterred from a bed of ice, where they were buried for ages, and the flesh has been found to be still in good condition.

The chief object of this article is the consideration of effects of low

temperatures; the other methods will therefore be mentioned but briefly.

The Use of Harmless Preservatives

Sugar and acids are perhaps the most important of these. By adding large amounts of sugar to perishable foods, such as berries or their expressed juice, and dissolving the sugar by heat, the berries may be kept in good condition for unlimited periods. The same result is obtained by the use of acids in the preparation of pickled vegetables, pickled meat, the curing of hams, etc. Spices also act as preservatives and many delicacies are preserved in oil.

The Use of Chemical Preservatives

Of these benzoate of soda, formalin, boric acid and salicylic acid are used to some extent. Whether these are unwholesome in the small quantities used is still disputed. The relative amounts are certainly very small and harmful results can only be incurred by continued use. Alcohol is also a powerful preservative and is produced by allowing fruits, etc., to ferment. The perishable grape is thus transformed into stable wine.

The Application of Heat

The enormous canning industry uses heat as a preservative, followed by exclusion of air. First the microorganisms are destroyed by heat and then renewed invasion is prevented by sealing the containers hermetically. Temperatures, lower than those used for canning, are applied in pasteurizing milk and beer. Pasteurization is carried out by heating milk or beer from 140 to 145° F. for 20 to 30 minutes. This process does not kill all microorganisms, but the great majority, including disease germs. If pasteurized milk is cooled rapidly and kept cold it will remain sweet for days. Pasteurized beer will keep much longer, since the amount of alcohol contained in it aids in protecting against decomposition.

Conservation by Desiccation

Desiccation—the abstraction of water—has been applied to the preservation of fruits, meat, eggs and milk. Fruits are dried in the open air exposed to the sun or by artificial heat. Desiccated products, of course, can be of no better quality than the original substance. Poor fruit, dirty milk, decomposed meat and aged eggs can not be expected to improve by desiccation. Milk should be clean before desiccation, but unfortunately this is not often the case, and the production of eggs is not as sanitary and well regulated as might be desired. Eggs are rarely, if ever, sterile when freshly laid, the term sterile applying to the total absence of microorganisms. It is certain that, after laying, bacteria

can penetrate the shell, especially if the shell is moist. These bacteria find excellent food in eggs and will multiply at an enormous rate unless the eggs are kept cold. The producer usually brings the eggs once a week to the country store, where they remain for another week or two before being delivered to a factory for desiccation. When we consider that one bacterium may have a progeny of 17 millions in 24 hours under favorable food and temperature conditions, it is not surprising to find that eggs used for desiccation contain millions of microorganisms. Bad eggs are usually recognized by holding them up to a bright light in a dark room, a process known as "candling." This will reveal dark spots resulting from bacterial multiplication, or colonies of molds, or embryonic development of the chick. But we must remember that millions of bacteria take up a smaller space than the head of a pin, so that the process of candling will show their presence only after enormous multiplication has taken place. On the other hand, if fresh eggs are desiccated within a few hours or a day after laying and have been kept cold during this interval, the final product will contain about the same number of bacteria as the original eggs. It must not be assumed, however, that the presence of many millions of bacteria is necessarily injurious to health. Of all species of bacteria known to science an exceedingly small number is injurious, and these are rarely found in eggs.

Conservation by Cold Storage

The present methods of cold storage are the natural result of evolution from the practise of using the cellars of farmers and produce dealers. Surplus food material is stored in warehouses, where it will keep in good condition for various periods of time, these periods depending largely upon the degree of temperature maintained. Such storage makes possible an artificial season, which may be long enough to bridge the gap between one producing season and the next. The importance of this can not be overestimated and has found expression in the fact that the Canadian government is subsidizing cold-storage plants.

The degree of temperature to which foods are exposed in cold storage varies according to the nature of the food. Fruits, vegetables and and shell eggs are permanently injured by freezing and are therefore kept just above the freezing point. If eggs are broken, the yolks and whites mixed and then frozen, they can be preserved for a long time. What has been said about desiccated eggs applies with equal force to frozen and cold storage eggs. If they are in good condition when placed in cold storage or when broken for freezing they will keep for a long time. Usually considerable deterioration takes place before they reach the packer. Especially is this true of summer eggs. April and May eggs, if placed in cold storage in good condition, are of better quality

than so-called fresh eggs during the summer months. The popular prejudice against cold storage eggs is not entirely unjustified, since eggs are sometimes stored after having become tainted. As a rule, they are well taken care of after they reach the packer, while the producer uses no precautions to preserve their original condition. It is probable, that there are more tainted eggs sold, that have never been in cold storage, than tainted cold storage eggs. Microorganisms multiply slowly, if at all, at the freezing point. Scientific investigations have not settled this point satisfactorily. Some bacteria may survive at very low temperatures, but freezing gradually kills most of them, as has been demonstrated by bacteriological studies of ice. It has been shown also that the number of bacteria in eggs in cold storage decreases constantly to a point where but few are left. Some observations are on record which seem to show that bacteria may multiply slowly near or below zero. This subject needs more thorough scientific investigation. However, it is safe to say that eggs placed in cold storage in good condition will remain practically unchanged for many months.

Meat, poultry and fish are stored in large quantities in the frozen condition. It is perhaps not generally known that cattle are most plentiful during the three months of late summer and early fall, although there is a limited supply during the remainder of the year. The packers buy all the cattle obtainable, slaughter it, supply the immediate demand and place the surplus in cold storage. When the season of plenty has expired they can draw on cold storage stock and keep the market supplied. Thus prices are kept more or less balanced during the entire year. This is of inestimable value. The prices remain within the limits of every one and a plentiful supply can be carried over from one season to the next without allowing any to go to waste. The meat inspection service carried on by the government is well organized. Every piece of meat handled by the packer has a definite record and consequently only fresh meat is placed in cold storage. It is authoritatively stated that federal or state inspection of eggs and fruits destined for cold storage would be welcomed by all reputable packing houses.

Packers usually have three warehouses, a different temperature prevailing in each one. The fresh meat is hung in the "chill room" at a temperature of 32° F. The temperature gradually rises to about 40° F. while the room is being filled with fresh warm meat. The next morning the temperature is down to 32° F. again. The meat is then removed to the "freezer." Here a temperature of —9 to —12° F. is maintained and the meat left for two to four days. It is now frozen throughout and is transferred to the cold storage room and kept here at 12 to 15° F. This temperature is low enough to keep meat in a frozen condition. Poultry and fish are treated in a similar fashion.

The handling of poultry for cold storage is not as well regulated as that of meat. A large amount of poultry is killed on the farm, instead of at the packing house. From the farm it may be shipped by two methods, the "wet" and the "dry." If shipped "wet," the poultry is packed in ice and the skin becomes wet and softened, so that bacteria can penetrate readily. If shipped in modern refrigerator cars, which are recharged with ice every day, the poultry remains "dry" and arrives at the cold storage warehouse in good condition. Poultry is frozen either with the entrails (undrawn poultry) or after the entrails have been removed (drawn poultry). Formerly it was thought that the presence of the entrails had an injurious effect upon the keeping qualities and in some places ordinances have been framed prohibiting the shipment of undrawn poultry. Recent investigations have shown conclusively that undrawn poultry keeps in better shape than poultry drawn in the ordinary fashion. The fundamental cause for the difference in keeping qualities of drawn and undrawn poultry is the presence of bacteria in large numbers in the entrails. In the ordinary process of drawing, of which there are different methods, the membranes of the body cavity can not escape injury and bacteria invade the muscles. The membrane remains intact if poultry is not drawn, or drawn carefully. For practical purposes it is no doubt preferable to allow the entrails to remain until the poultry is prepared for consumption. Recently poultry has been frozen in paraffined pasteboard boxes, which are delivered to the consumer in a sealed condition and with proper directions for thawing. Frozen poultry should be thawed slowly in a house refrigerator, which process requires about two days.

The handling of fish for cold storage is surrounded with difficulties. Fish is not part of our daily diet as meat is, but is consumed largely on one day of the week. The fisherman may have a large haul or a small haul. If large, there will be surplus to be disposed of. A number of fish are frozen together, forming cakes of about 20 pounds each. The cakes are piled up on top of each other in a cold storage warehouse. The ice hermetically seals the fish, but every well regulated cold storage warehouse has some provision for ventilation and the moving air takes up the evaporating ice from the free parts of the cakes containing the frozen fish. The heads become exposed and are recovered with ice by periodical sprinkling and dipping. This requires considerable attention on the part of the warehouse man, but if properly carried out will preserve fish for long periods. Thus waste is prevented and the market kept supplied.

Changes taking Place in Meat, Fish and Poultry in Cold Storage

The changes taking place in meat, poultry and fish during cold storage are both of physical and chemical nature. The physical changes are chiefly those which are due to freezing and thawing. More than one half of the muscle substance is water. When the temperature of water is lowered the volume is reduced, but below 39° F. increases again. Therefore, when the meat is chilled below 39° F. the water contained in the muscle cells filters through the cell membrane and fills the interstices between the layers of cells. Here it freezes when the meat is placed in freezer storage. Gradually the interstices are filled with crystals of ice and the cells are squeezed out of shape. If the meat is thawed the result will be different according to whether the thawing process is carried on slowly or rapidly. If slowly, the water will filter back into the cells and they will assume, nearly at least, their normal shape, and the meat will, to all outward appearance, look like fresh meat. If the meat is thawed rapidly, considerable juice will ooze out and the cells will never resume their normal condition. It is better, therefore, to thaw meat slowly.

Some of the water contained in the skin naturally evaporates during cold storage, so that the skin shrivels. To restore the natural appearance and replace the lost weight, frozen poultry is frequently soaked in hot water. This softens the skin and favors the invasion of bacteria. Poultry treated in this fashion will deteriorate rapidly and the practise should therefore be condemned. The physical changes described do not injure the general appearance, flavor and digestibility of the meat, some investigators claiming that both flavor and digestibility are favored.

Whatever *chemical* changes take place in meat, poultry and fish in cold storage are chiefly the result of the activity of microorganisms (bacteria and molds). Since, however, bacteria multiply slowly at the freezing point, and probably not at all in frozen meat, the changes are slight. At 32° to 40° some changes are noticeable after 15 days' storage. These changes are also slight and are restricted not only by the temperature, but also by the layer of dry meat forming on the outside, which makes it difficult for bacteria to penetrate the interior.

The fat is probably not attacked by bacteria, but undergoes a slow oxidation under the influence of light and the oxygen of the air. By this process the acidity of the fat increases, but the change is very slow, if the meat is kept frozen, and is not noticeable for months. It has also been claimed that there is some change in meat due to the action of ferments, which may be contained in the muscle cells. This process is called "autodigestion." There is, however, no reliable evidence of this; in fact, new investigations seem to show that bacteria are the only agen-

cies worthy of consideration in the decomposition of meat. Ferments, moreover, do not act at very low temperatures, although they are not destroyed and resume activity when meat is thawed.

Whether bacteria multiply at freezer temperature in liquid foods is problematical. It is well established that bacteria die gradually in ice so that after several months ice is practically sterile. Ice, however, offers little nourishment for bacteria, while meat contains plenty of food, which is available if water is present. Bacteria can not multiply in solid substances and therefore multiplication in frozen meat is impossible. It is reasonable to assume that bacteria will die in frozen meat as they do in ice. Conditions of frozen fish are quite similar to those of meat and poultry. A few investigations of this problem are available and, in substance, agree with the findings in frozen meat and poultry. The bacteriological aspect of cold storage meats is largely speculative and scientific investigations are much needed to throw light on the problems of cold storage.

In a general way the conclusions reached by those investigators who have worked on cold storage problems are that there is no appreciable difference in chemical composition between fresh meat and meat kept frozen for periods longer than two years. No progressive changes could be determined with precision. In regard to frozen poultry it has been stated that the changes in chickens in 24 hours at 65 to 75° F. are greater than in cold storage at 10° F. for 12 months. The changes taking place in cold storage for 12 months are comparable to storage in a house refrigerator for 5 days, or in the packer's chillroom at 32° F. for 15 days, this not being sufficient time to bring about the tenderness and flavor of so-called "ripened" meat. Most chickens bought in the market as fresh are of poorer quality than chickens frozen for 12 months, and are poorer than many kept in cold storage for 16 months.

The conclusion is inevitable that cold storage at 10° to 15° F. has no deteriorating effect on the condition of meats, poultry and fish for a period long enough to bridge over the time from one flush season to the next, that is to say, for about 12 months. The term "deterioration" is a vague one and is interpreted largely on the basis of individual opinion and taste. Some foods are not considered fit to eat unless they have "ripened," but the ripening process is nothing but a decomposition brought about by bacteria and molds. Cheeses of all kinds are permitted to ripen for various periods of time and the changes taking place during the ripening process are comparable from a chemical point of view to the so-called deterioration of meat. The most delicate and savory steaks are subjected to a ripening process, which consists in storing them for 30 to 60 days at a temperature of 32°–40° F. During this time the muscle fibers undergo changes, which render them more soluble and consequently more tender, palatable and digestible. This is

practically the same process as the ripening of cheese, with this distinction, that decomposition of cheese is allowed to go farther than decomposition of meat. It is also true, that the tastes of individuals differ largely. Game is usually considered best when decomposition has gone far beyond that of ripened meat, and when it has developed the so-called "gamey" flavor, which is the result of progressive decomposition. Putrid eggs are preferred to fresh eggs by the Chinese, and rancid butter to fresh butter in some tropic countries. Some cheeses are most palatable to many people when decomposition has gone so far as to produce decay. The cheese then contains considerable amounts of ammonia, a sure sign of advanced putrefaction. Virginia hams after two years' storage are considered at their best by connoisseurs.

It can readily be seen that it is difficult to establish a limit in a process and call it ripening, while the same process continued for some time would be called deterioration. All standards to-day are arbitrary in the light of our knowledge and the judgment of health officers is seriously taxed. It is obvious that it is largely a matter of opinion, and it is certain that much investigation, chiefly from a bacteriological point of view, is necessary before intelligent legislation can properly take care of cold storage. Recently a bill was introduced into the federal senate, which proposes to limit the time of cold storage of beef to 7 months; of pork and mutton to 4 months; of poultry, game, fish, eggs and butter to 3 months. By such limitation the very purpose of cold storage is defeated and, in the light of our knowledge of cold storage problems, entirely unjustified. Regulation of commercial cold storage should be attacked from two standpoints: (1) Cold storage warehouses should be subject to government inspection as to construction, ventilation, temperature and sanitary conditions. This inspection should also be extended to refrigerator cars. (2) All foods destined for cold storage should be inspected as meat is inspected at the present time.

Poultry should be placed in cold storage only when fresh and the killing should be done by the packer. It should be stored undrawn. Under a system of inspection there is no reasonable doubt but that food coming out of cold storage would be in as good condition as when going in. Legislation limiting cold storage is entirely out of place. It is true, that foods coming out of cold storage decompose more rapidly than fresh foods, not because—as has been suggested—fresh food is still "alive," but because the physical structure has been changed to some extent by freezing, rendering the food more accessible to bacterial invasion.

The cold storage warehouse is an all-important asset to modern economy, but the facilities are limited at present. It has been stated that in Greater New York about two million pounds of meat are kept in cold storage, while the weekly consumption of meat is 80 million

pounds. If a storm or some other calamity should prevent the shipment of fresh meat the cold storage supply would last but a short time and a meat famine would follow.

It seems clear that cold storage is a great boon to man at present and will be of greater value in the future. Not many years ago, before cold storage facilities were generally available, it was not an uncommon occurrence to buy tainted meat from recently slaughtered animals. The animals had to be killed in places where flies were common and the meat offered favorable breeding places for the pests. Modern sanitary slaughtering houses with the addition of cold storage facilities have conquered many evils of similar nature. The cold storage industry should receive the hearty support of the public and it should be the aim of legislators to protect legitimate cold storage by appropriate regulations. This can not be brought about until the great problems involved have been thoroughly investigated both from a scientific and commercial point of view.

THE WORLD'S MOST IMPORTANT CONSERVATION PROBLEM

By STEWART PATON, M.D.

PRINCETON, N. J.

THE world's most important problem is the discovery of methods of conserving and increasing the brain power of mankind. If we are judged by our ignorant and reckless dissipation of energy of the most complicated organ, which the process of evolution brings to us as a priceless heritage, we are still in the infancy of the race. Life, movement and being depend upon the activity of the brain and nervous system, our superiority over the lower animals is the result of greater brain power, while our relative ranking as members of the human family is commonly rated by the amount of "brains" we possess. Individual success no less than national greatness is proportional to brain power. A victory in modern warfare is a sign of greater mental efficiency than was necessary among the soldiers a century ago, while the efforts to win success in peace have lined the roads leading to the mountain tops with a far larger number of those who are mortally wounded in spirit than ever fell on the field of battle.

One of Napoleon's greatest errors was his failure to become interested in Pestalozzi's scheme of national education on the ground that he had no time to trouble about the alphabet. The conqueror forgot that brains and not brawn rule the world. In the great struggle of modern civilization, success as well as life depends upon the functional capacity of the brain and nervous system. What will the lessons of history profit or the teachings of wise men avail if these organs are too weak to translate precept into action?

It is a mere truism to affirm that the ultimate destiny of our civilization will depend upon the degree of efficiency developed by the brains of the members of future generations; but the importance of self-evident truths is seldom appreciated. If human intelligence is measured by the interest we take in the problem of the greatest importance in determining the destiny of the race, what shall we say of our ignorance and lack of forethought with regard to the most vital of all human problems? Modern civilization is constantly increasing the strain on the most delicate organ in the human body, while but puny efforts are made to supply the opportunities for obtaining the information about the brain necessary to avert disaster from overwhelming the

human race. While speaking in hysterical tones of a possible shortage of the wheat crop, or expressing gloomy forebodings of the failure of the coal supply, we are blind to the fact that some day there may be a shortage of brain-power, a deficiency made evident by our failure to cope successfully with the emergencies created by an advancing and more complex civilization. Universities, and so-called higher institutions of learning, do but little to encourage any effort made in the direction of finding out the laws which condition the activities of the brain. In relative importance all other questions become mere trivial academic discussions. If the public does occasionally discuss these topics it is "as if it had been struck by sentimentality."

Each new crisis in civilization calls for the exercise of more intelligence. Instead of having our wits about us and discussing the ways and means of developing greater cerebral capacity, we talk glibly enough about the man behind the gun, but make no effort to increase his mental efficiency. Although the success of representative government depends upon the fact that the majority of voters should have sound minds in sound bodies, we are more interested in the framing of new statutes than in any attempt to promote the mental growth of the citizens. Over the entrance to the New York Public Library the following words are inscribed: "On the diffusion of education among the people rests the preservation of our free institutions." This affirmation is true only if we include in "education" those agencies which aim to protect the brains of the people from injury. The nineteenth century supplied indiscriminately countless opportunities for squandering brain energy, and it now becomes the duty of the twentieth to determine the speed limits and endurance tests to which the most delicately balanced organ in the human body may be subjected without imperiling individual or racial existence.

In order to increase the brain power of a nation steps should be taken to conserve that which exists. Any reform which has this end in view should begin by taking cognizance of all the facts directly related to the problems under discussion, and then efforts should be made to provide the means and opportunities for extending our knowledge of this subject. In the movement to conserve the national forests the schools of forestry are not only repositories for knowledge, but are centers for investigations; the sources for information that vitalize the whole movement. An organization based on similar principles must form the basis of successful attempts to conserve all of our national resources, rivers, harbors, coal, forests and brains. First, there is the immediate attack in which the present store of knowledge is catalogued and presented to the public in an assimilable form. The popularization of the scientific knowledge of the brain will be one of the duties of the National Committee for Mental Hygiene. Equally important is the

establishment of bases or centers for the consideration of plans for acquiring additional facts to be used in winning the future battles against ignorance; and it is to this second plan of campaign, the discussion of methods for acquiring information, that attention is to be briefly directed.

In order to understand the methods employed in the study of the brain and nervous system attention must be directed to certain fundamental laws which are applicable to all forms of living organisms. Life will continue to be a subject of increasing interest to mankind, and the values of all forms of knowledge will be estimated by the better understanding that they give us of vital phenomena. During his early development man's interest in biology was chiefly limited to interpreting the phenomena of more common occurrence in his own life history, and to-day we observe the same egoism in savage races. Gradually educated people have awakened to a realization of the fact that the vital phenomena of plant and animal life vary in degree but not in kind from those observed in the human species. As a result of a limited horizon and a centripetalizing thought process man was led to assume a place of unique grandeur in the universe for himself, and this anthropocentric point of view not only dominated but seriously interfered with the actual progress made in the study of the brain. The concepts of this false philosophical system unfortunately limited the study of the nervous system to the human subject, whose nervous system represents the most complicated series of organs in the animal series. But more unfortunate than the establishment of false standards by which man's relative importance in nature was measured was the consequent diversion of human interest from the consideration of problems of the most vital importance to humanity. This was one of the penalties paid for assuming that the human brain had definite and specific functions not represented in other animals. The egoism of mankind is reflected in our present superstitions and ignorant attitude in regard to the questions connected with the cure and prevention of insanity. Attempting to conceal our defects by clamorously referring to our position of splendid isolation in the universe, we have failed to plan a rational system of education, and have been content to try to drive all who applied across the intellectual tight rope without any effort being made to determine the capacity of the individual nervous system to maintain its equilibrium while under strain or to restore it if disturbed. The results of these sins of omission afford excellent examples of the practical cruelties to which humanity is, as Anatole France has said, so often subjected by the sickly sentimentality that periodically is a blight upon our intelligence. Physicians compelled by the exigencies of practise too often confined their studies of anatomy and physiology to the organs of the human individual and thus unconsciously sanctioned

the view that the functions of man's brain and nervous system were specifically different from those of the lower animals. After centuries of hopeless wandering in a labyrinth, investigators at last picked up the ariadnian thread that connects the behavior of the simplest organism with the complex mental life of man, and students have come to realize that in the simpler structure and more easily analyzed functions of ameba, jelly-fish, crab or fish, is to be found the key that will eventually open the book in which we may read intelligently concerning the most complex psychic manifestation.

This change in our point of view is not only of philosophic but of great practical value. The student of the brain is no longer a Sisyphus. Investigators now know that a fact discovered in relation to the nervous system of worm or jelly fish may unlock some of the secrets of the physiology of man's brain. The advance from the study of the simpler reactions of the lower organisms to those of the higher animals is made by easy stages, and the knowledge that the continuity of the chain is unbroken is a source of hope and inspiration. Already the nervous system has been deprived of the mysterious specific properties which once it was supposed to possess. Eminent physiologists tell us that it has only those properties which are found to be distinctively characteristic of protoplasm, the physical basis of life. The capacity for receiving stimuli coming from the external world, of transforming, transferring and storing these impressions is characteristic of living organisms. Plants have the power to pick up and transmit a stimulus. An example of this power is seen in the closure of the leaves of the sensitive plant after being touched. As far as is known, however, plants do not have a differentiated nervous system, but between the various cells of which they are composed there are countless connections probably forming paths for the conduction of impulses. These conditions are not unlike those found in embryos of the higher animals at the time when the movements of heart and body have already begun, but before nerves have developed.

The study of the lowest organisms teaches us that the conductions of nervous impulses occur independently of nerves. More recent studies have led investigators to believe that the nervous system does not in any sense create function, but is to be regarded merely as the great regulator, the transforming apparatus called into existence to assist in preserving the equilibrium of each living organism, amid a play of energies, light, heat, electric waves, etc. As long as the equilibrium is undisturbed we say that the body is in a state of rest, but let that balance be disturbed by any stimulus and a reaction takes place. In comparison with other animals, some of our sense preceptions are very limited as our end organs or receptors are only attuned to pick up waves of certain lengths. Other living organisms, as, for example, many insects,

have the capacity of picking up sound waves of a much higher pitch than those which impress our duller senses, while the greater acuity of vision of birds, the keener sense of smell of various animals, the delicacy of perception of fishes for changes in pressure, are facts that are too well known to need repetition. To a certain extent these great differences in sense perception are directly referable to peculiarities in structure. The same fundamental system of construction characterizes the nervous system of the entire animal kingdom. The structural unit is the nerve-cell and nerve-fiber. The greater the number of these cells and fibers the greater is the complexity of the nervous system. Some of the cells are designed to pick up and transfer to the distributing apparatus the stimuli for which the organs are attuned. In addition to the receiving apparatus there is the transformer and elaborator of the incoming impulses, and finally there is the discharging apparatus as represented by the organs of locomotion, speech and others, which express objectively the sum total of the animal's activities. Already science has taught us something about the nature of that mysterious nervous impulse upon which thought, action and life depend. In fact there is a similarity between the rhythmic character of the life processes and the rhythmic discharges of certain types of cells in a battery. Here, as in all other enquiries which concern the energies of living matter, we are led back to the study of the cell. The millions of cells composing our bodies have certain common characteristics. The central portions are probably the parts most immediately related to the production of energy, while the external layers govern the taking in or throwing off of substances by the cell. A theory in regard to the manner in which anesthetics act attributes an important rôle to this external layer, as the place where the actual physico-chemical changes take place that result in anesthesia. The effects depend to a certain extent upon the presence in this outer envelope of certain fat-like substances which, combining with the enhaled ether or chloroform, produce loss of consciousness. There are also reasons for believing that in this same external layer of the cell the nerve impulse is generated, depending upon changes akin in their manifestation and mode of origin to those giving rise to electrical disturbances. One of the greatest services yet rendered biology by physical chemistry is the presentation of the facts suggesting that the regulation of the production of nerve impulses is not dependent upon some vague mysterious vital force, but is probably comparable to those phenomena called by the chemists "reversible reactions." The mixture of two substances may be followed by a chemical reaction in which the two original substances are in part decomposed, forming new chemical compounds. At a certain point this reaction ceases, as an equilibrium has been established, and then only after the balance has again been disturbed is the decomposition completed or a

restitution of the original bodies brought about. Physical conditions alone determine the direction taken by these "reversible reactions." This phenomenon suggests a possible explanation of the changes taking place in nerve cells and the relation they bear to the production and regulation of the nerve impulse.

Within the past decade biologists have discovered many facts that throw considerable light on the relation that the nervous system bears to the growth of the organism, and they have also arrived at certain conclusions of great importance in regard to the manner in which nerve cells grow. Portions of living tissues, nerve as well as muscle, or the supporting elements of the body may be removed and grown outside of the animal. Photographs taken at short intervals of nerve cells placed in various artificial media which are kept at the body temperature show a remarkable series of changes. In a comparatively few hours these cells may actually be seen to throw out long processes resembling the embryonic nerves.

A limited space does not permit more than a passing reference to the advances made, and largely by American investigators in the study of animal behavior. These newer methods of study, says a distinguished English scientist, "contrast with the anecdotal method of the past generation almost as pronouncedly as do modern chemical methods with those of the medieval alchemists." Modern biology with the inspiration derived from the physical and chemical laboratory has already brought new life into the discussion of such old questions as that of variation and inheritance in living beings. To answer the question "What are the traits inherited by our nervous systems?" we must follow the paths mapped out by the new biology. The way of the statistician has been followed until the new road offered by experiment is within our sight.

Posterity will, as we have already indicated, measure our intelligence by the interest we take in acquiring information in regard to the organs upon the functional development of which depend our continued existence as a race. In the various medical schools and hospitals throughout the country the problems connected with the human brain and nervous system will continue to be subjects that have an immediate claim upon the attention of physicians, but even in these institutions these questions should not be forcibly disassociated from the consideration of more fundamental biological phenomena. The possibility of extending the scope of the work carried on in the biological departments of our universities so as to facilitate and encourage investigations in the broad field of biological psychology would be an important factor in bringing these institutions into the closest touch with the subjects of most vital importance to humanity. But in addition a new type of institution dedicated to the study of neuro-biology is greatly needed. The Phipps Psychiatric Clinic in Baltimore will mark a new era in this

country not only in the study of nervous and mental diseases, but also in advancing our knowledge of many questions of immediate importance for educators and those interested in the solution of social problems. The way has been prepared by science for the establishment of a new type of institution dedicated to the study of the brain and nervous system along broad biological lines. This field of investigation would include, for example, such problems as an enquiry into the nature of the nerve impulse, the manner in which it is transmitted, the changes produced by it in the body, the agents modifying its action, the factors determining the growth of the nervous system and the possibility of inducing regeneration, after the nerve cells and fibers have been injured, and the mechanism of transmission by heredity of specific functions of the brain. The neuro-biological institute should contain laboratories fully equipped for the study of complex chemical and physical problems, the determination of the laws of animal behavior, the mechanism of development of the nervous system as well as the character of structure of these organs. The selection of investigators should be made with care and the greatest amount of liberty given to them in selecting and determining the scope of their own problems, for in attempting to answer the questions of fundamental importance in connection with the brain and nervous system we are brought face to face with a line of work which leads us straight back to consider the origin of the life processes.

The advance of humanity during the past fifty years has been illuminated by the acts of an intelligent philanthropy. The noble list of benefactions includes libraries, schools, colleges, universities, laboratories, observatories, hospitals and an international tribunal for the abolishment of wars. The future progress of mankind will be directly proportional to the additions made to our knowledge of the brain and nervous system. Whether the conventional form of education proves to be a blessing or a curse will depend upon its power to minister to the needs of brain and nervous system. The reign of universal peace will come at last, not as an official act of international agreement, but as the result of the study of the individual and the adoption of methods to suppress and eliminate those undesirable mental traits which at times make the resort to arbitration impossible.

Far more important than the discovery of a new continent or a new star is the determination of the laws governing brain action, for upon our knowledge of these phenomena depends "the prosperous voyaging of humanity."

TRINIDAD AND BERMUDEZ ASPHALTS AND THEIR USE IN HIGHWAY CONSTRUCTION. II

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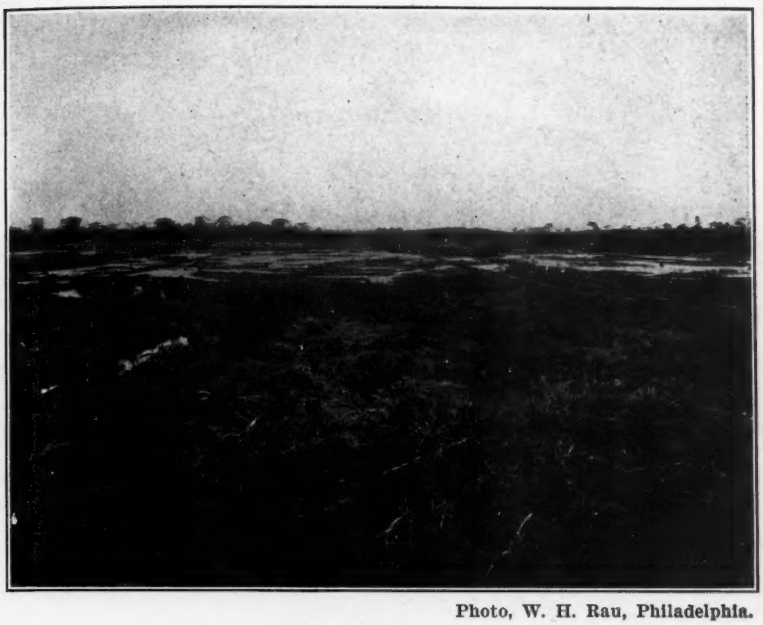
The Bermudez Asphalt Deposit

From the mouth of the Orinoco, the northeastern coast of Venezuela, which faces Trinidad, is low and consists of vast mangrove swamps, through which run deep tidal estuaries. That portion forming part of the State of Bermudez extends inland for many miles. It lies on the opposite side of the Gulf of Paria from Trinidad. About 30 miles in an air line from the coast the asphalt deposit, known as the Bermudez pitch lake, is found at the point where a northern range of foothills comes down to the swamp. The Guanaco River, a branch of the San Juan, one of the large caños or estuaries of this region, at about sixty-five miles, in its winding course, from its mouth, runs within three miles of the deposit, but it is five or six miles to a suitable wharfage site. On the other hand, towards the north, a road runs to the hills and to the village of Guaryquen. These are the means of communication with the deposit. The so-called lake is situated between the edge of the swamp and the foothills in what might be termed a savanna. It is an irregular-shaped surface with a width of about a mile and a half from north to south and about a mile east and west. Its area is a little more than 900 acres, and it is covered with vegetation, high rank grass and shrubs, one to eight feet high, with groves of large moriche palms, called morichales. One sees no dark expanse of pitch on approaching it as at the Trinidad pitch lake, and except at certain points where soft pitch is welling up, nothing of the kind can be found. The level of the surface of the deposit does not vary more than two feet and is largely the same as that of the surrounding swamps. In the rainy season it is mostly flooded and at all times very wet, so that any excavation will fill up with water. These conditions make it difficult to get about upon it or to excavate pitch easily.

It is readily seen that this deposit is a very different one from that in the pitch lake of Trinidad. It seems to be in fact merely an overflow of soft pitch from several springs, over this large expanse of savanna, and one which has not the depth or uniformity of that at Trinidad.

At different points there is at most a depth of 7 feet of material,



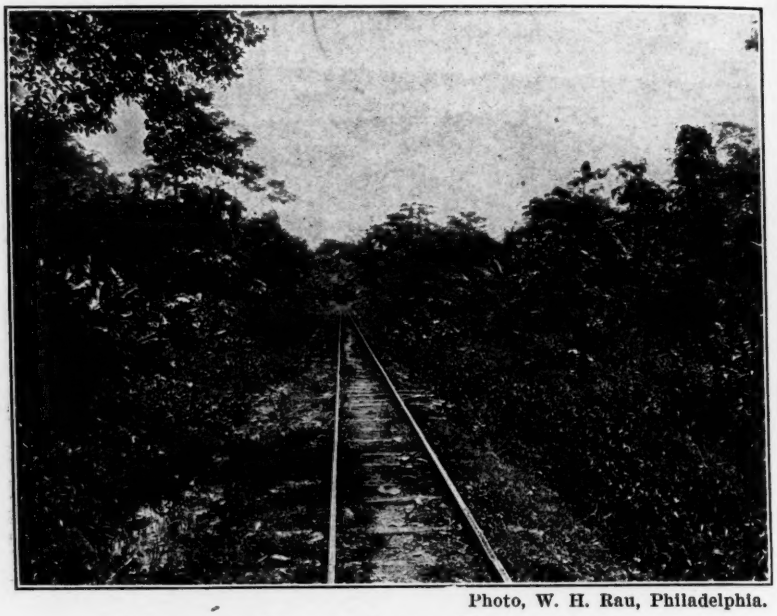
Photo, W. H. Rau, Philadelphia.

BERMUDEZ PITCH LAKE, VENEZUELA.

while the deepest part of the soft maltha is only 9 feet and the average of pitch below the soil and coke only 4 feet. At points there is not more that 2 feet of pitch, and in the morichales or palm groves it is often 5 feet below the surface. At several points scattered over the surface are areas of soft pitch, or pitch that is just exuding from springs. The largest area is about 7 acres in extent and of irregular shape. This has little or no vegetation upon it, and from the constant evolution of fresh pitch is somewhat raised above the level of the rest of the deposit. This soft asphalt has become hardened at the edges, but when exposed to the sun is too soft to walk upon. The material is of the nature of a maltha and it is evidently the source of all the asphalt in the lake, from these exudations the pitch having spread in every direction, so that no great depth of pitch is found even at this point.

A careful examination of the surroundings shows that in one respect there is a resemblance between the point of evolution of the soft pitch at the Bermudez and at the Trinidad lakes. Gas is given off in considerable quantities at both places, and in both cases consists, partly, at least, of hydrogen sulphide.

The consistency of the soft pitch at the center of the Bermudez lake is much thinner than that of the Trinidad lake. It will run like a heavy tar and does not evolve gas in the same rapid way or harden as quickly after collection. It therefore does not retain the gas which is generated in it, nor does the deposit as a whole do so to the same extent as the Trinidad pitch.



Photo, W. H. Rau, Philadelphia.

RAILWAY FROM BERMUDEZ LAKE TO WHARF AT GUANACO.

The general surface of the lake is very irregular and hard. There are many very narrow and irregular channels or depressions from a few inches to four feet deep, filled with water, and, not being easily distinguished, one often falls into them. At the foot of the growth of grass and shrubs are ridges of pitch mingled with soil and decayed vegetation, which have been plainly coked and hardened by fires originating in the surface growth. When this hardened material which forms only a crust is removed, asphalt of a kind suitable for paving is found. The crust is from a foot and a half to two feet in depth and very firm, while the asphalt underneath would not begin to sustain the weight which that of the Trinidad pitch lake does easily. There are breaks in the crust here and there through which soft pitch exudes, as has been described.

It appears, therefore, that the Bermudez deposit owes its existence to the exudation of a large quantity of soft maltha, which is still going on and which has spread over a great area; that this has hardened spontaneously in the sun, and has also, by the action of fire, been converted over almost the entire surface into a cokey crust of some depth, beneath which the best material lies, and that here and there are scattered masses of glance pitch produced in a similar way from the less violent action of heat. There is no evidence of a general movement and mingling of the mass of this deposit in any way that would produce a uniformity of composition, as seen in the Trinidad pitch lake, although there is a certain amount of gas evolved at the soft spots where maltha

exudes and some gas cavities are found in the general mass of the pitch beneath the crust. As the asphalt below the crust of the deposit is the only portion of value for paving, the question has arisen as to its uniformity.

An examination of a series of samples collected in 1894 shows that the asphalt from the Bermudez deposit may vary very largely in the amount of water which it contains, from 11 to 46 per cent. None of it, however, is present in the form in which it occurs in Trinidad asphalt. It is not emulsified with the bitumen, but is all adventitious surface water. The percentage of oils which it volatilizes at about 400° F. varies from 16 to 6 per cent., consequently the consistency is far from uniform. The material carefully selected for use industrially is fairly constant in character, however, and when carefully refined has the following proximate composition:

THE COMPOSITION OF REFINED BERMUDEZ ASPHALT

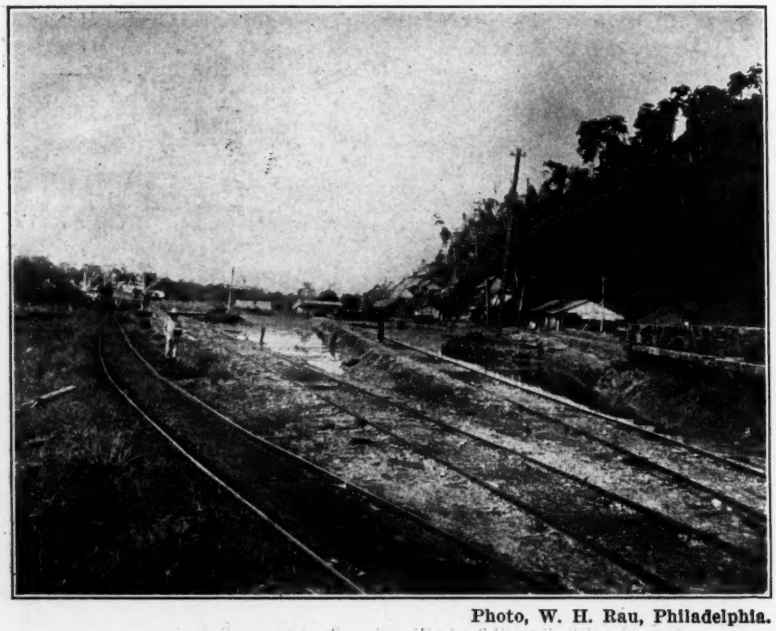
Specific gravity, 77/77° F., orig. substance dry	1.082
Color of powder or streak	Black
Luster	Bright
Structure	Uniform
Fracture	Semi-conchoidal
Hardness—original substance—at 77° F.	Soft
Odor	Individually asphaltic

Photo, W. H. Rau, Philadelphia.

DUMP OF CRUDE BERMUDEZ ASPHALT AT GUANACO.

Flows (melting point N. Y. T. L. method)	151° F.
Penetration at 77° F., 5 sec., 100 grams, No. 2 needle	3.0 mm.
Loss 20 grams 325° F., 7 hours, 2¼″ dish	2.9 per cent.
Character of residue	Smooth
Penetration at 77° F., 5 sec., 100 grams, No. 2 needle	1.2 mm.
Loss 20 grams 400° F., 7 hours, 2¼″ dish	7.2 per cent.
Character of residue	Smooth
Penetration at 77° F., 5 sec., 100 grams, No. 2 needle	.4 mm.
Loss 50 grams at 325° F., 24 hours, 2⅞″×1¼″ dish ..	3.9 per cent.
Character of residue	Smooth
Penetration at 77° F., 5 sec., 100 grams, No. 2 needle	.5 mm.
Bitumen soluble in CS_2 air temperature (70° F.) ...	94.6 per cent.
Difference	1.5 per cent.
Inorganic or mineral matter	3.9 per cent.
	100 per cent.
Bitumen soluble 88° naphtha, air temperature (70° F.)	67.3 per cent.
This is per cent. of total bitumen	71.2 per cent.
Carbenes—per cent. bit. insol. CCl_4 air temp. (70° F.)	None
Bitumen yields on ignition: Residual coke	12.9 per cent.
Sulphur	5.5 per cent.

It appears from the above that the Bermudez asphalt is differentiated completely from that found in the Trinidad pitch lake, by the absence of



Photo, W. H. Rau, Philadelphia.

RAILWAY TERMINAL AT GUANACO, PIER IN DISTANCE.

Photo, W. H. Rau, Philadelphia.

RESIDENCE AT GUANACO.

emulsified water and mineral matter. It is a much purer bitumen, a fact of no importance as far as its technical application in street paving is concerned, since the fine mineral matter or filler must be added to any asphalt cement in its use in such construction, but which is of advantage where the material is to be used in the construction of bituminous broken stone highways by the penetration process, owing to the greater ease with which the purer and more liquid material will enter into the voids of the broken stone.

The ultimate composition of the pure bitumen of Bermudez asphalt is much the same as that of the bitumen in Trinidad asphalt, as can be seen from the following comparison:

	Bermudez Pure Bitumen Per Cent.	Trinidad Pure Bitumen Per Cent.
Carbon	82.88	82.33
Hydrogen	10.79	10.69
Sulphur	5.87	6.16
Nitrogen	.75	.81
	100.29	99.99

Bermudez asphalt contains, like the Trinidad, a high percentage of sulphur, varying, however, according to the degree to which the material has become hardened at different points in the deposit. The softest material contains the largest percentage.

[1] Soft material, maltha.

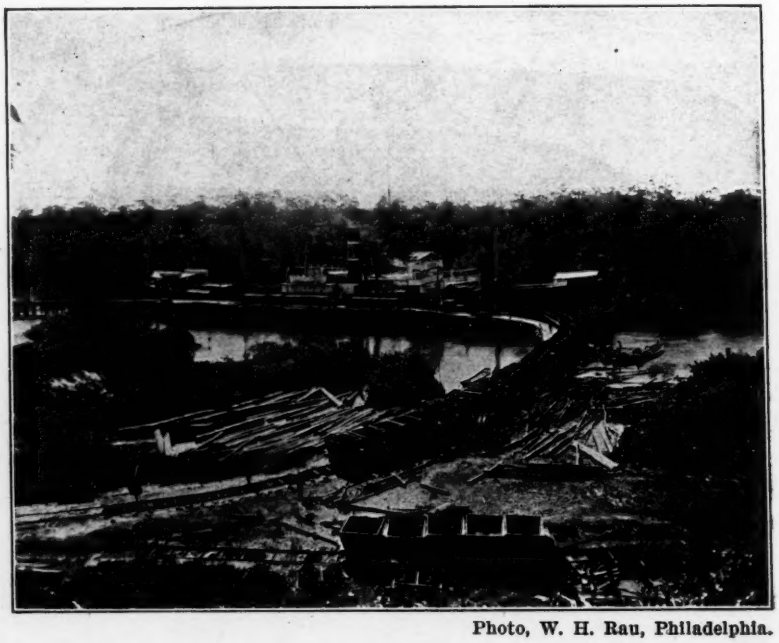
In this connection I would say that in a paper read before the New York Section of the Society of Chemical Industry in November, 1897, and published in the *Journal* of the Society for January, 1898, I stated that, in my opinion as the results of investigations extending over eleven years:

> Asphalt is in process of formation to-day. It plainly does not originate as such but is a secondary product resulting from the transformation of suitable lighter forms of bitumen, malthas or even thinner oils into harder bitumen by condensation and polymerization. A reaction in which sulphur, and probably sulphates seem to take an important part.

This conclusion was based on the fact that an ultimate analysis of the pure bitumen from fourteen solid asphalts from various parts of the world, showed the presence of from 9.76 to 4.78 per cent. of sulphur, while in the softer forms of bitumen which rapidly harden on exposure to the atmosphere, or on heating, notable amounts of sulphur, 2.0 per cent. or over are found.

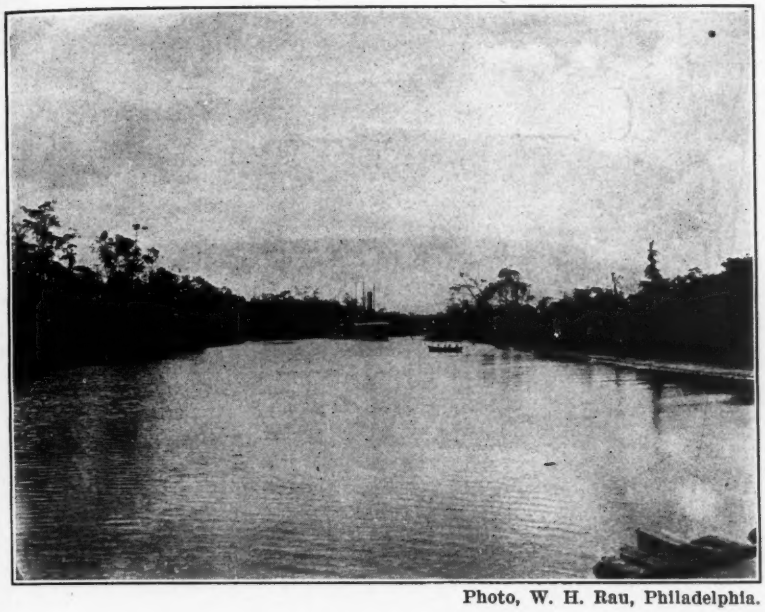
The same conclusion seems to have been arrived at, independently and apparently without a knowledge of my investigations, by Dr. D. Holde, of the Royal Testing Laboratory near Berlin. In his book on mineral oils and fats he says:

> A bitumen would be called native asphalt when it contains considerable amounts (2–10 per cent., usually over 4 per cent.) of sulphur not removable by



Photo, W. H. Rau, Philadelphia.

PIER AT GUANACO.



Photo, W. H. Rau, Philadelphia.

GUANACO RIVER AS VIEWED FROM PIER.

steam, when the amount of the latter in the chloroform extract which is insoluble in benzol is at least 7.5 per cent. and the asphalt, separated according to the method of Marcusson and Erckmann, contains 1.4–3.1 per cent. of oil with at the most 0.6 per cent. paraffin.

A bitumen would be called a petroleum residual pitch if it contains at most 1.7 per cent. of sulphur, even in the chloroform extract prepared as previously described and further 26–59 per cent. of oil in which the paraffin amounted to 3.3–16.6 per cent.

These conclusions of Holde are confirmed by my own data given in the paper to which I have referred, and are of the greater value on that account.

It appears, therefore, that a native solid asphalt is characterized by the fact that it contains sulphur, and the same thing is true, though in a lesser degree, of the softer bitumens from which it is derived.

Aside from the mere fact that sulphur is present in asphalt it is undoubtedly true that some of the most important physical characteristics of the material and those which distinguish it from the residual pitches are due to its presence, that is to say, the greater lack of susceptibility to change in consistency with change of temperature in the solid asphalts than is the case of the residual oils and pitches.

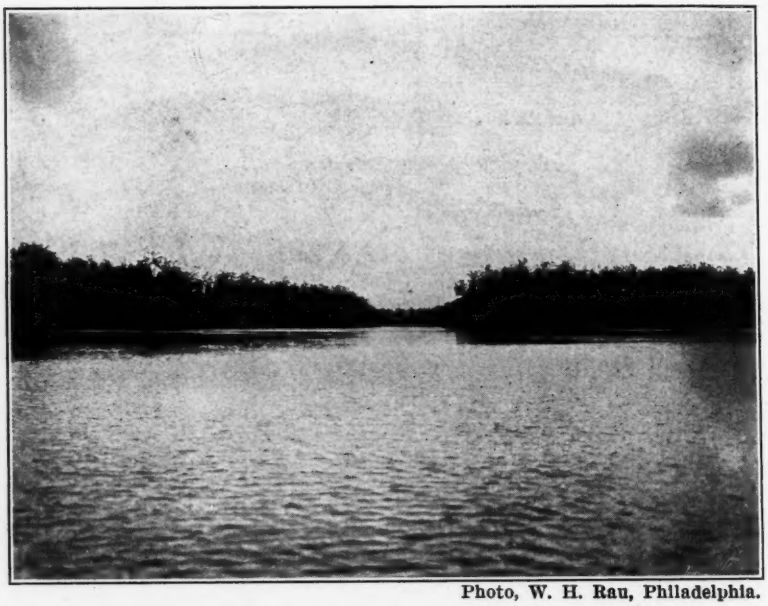
It is the presence of such a large amount of sulphur derivatives in Trinidad and Bermudez asphalt which makes them so desirable for use in highway construction, as compared with the residual pitches pre-

pared from petroleum oil, which contains practically no sulphur derivatives.

In proximate composition Bermudez is very similar, as far as the bitumen is concerned, to that of the Trinidad material. The proportion of malthenes is slightly larger, and the asphalt in consequence somewhat softer, but in general, it is of a very similar character.

Shipping the Asphalt

As will be seen in the accompanying illustrations, the crude asphalt is won from the surface of the pitch lake by laborers with picks, in the form of flakes which have been mentioned. Those are thrown into



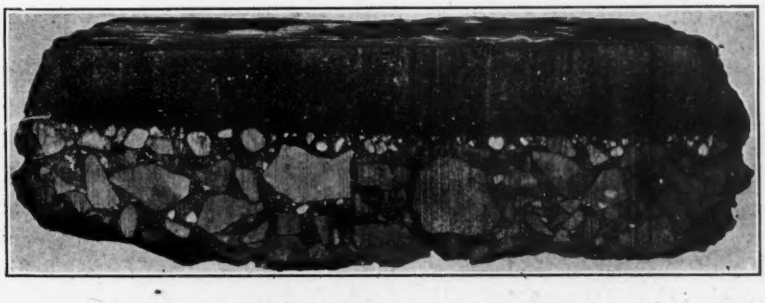
Photo, W. H. Rau, Philadelphia.

Guanaco River, Venezuela.

skips carried on small platform cars, which are run over the surface of the lake in a loop by cable, the rails being supported by palm-tree ties, which must be realigned almost daily, owing to the movement of the surface of the pitch. The loaded skips are brought to the terminal station at the shore of the lake, where they are hoisted and dumped into other skips, which are carried on a cable-way down the surface of the country between the lake and the shore, and out into the ocean on a pier some thousand feet in length, where they are emptied into chutes and dumped into the hold of the vessel awaiting a cargo. A thousand tons or more can be put on board a large steamer in this way in a day. During a large part of the year, three to nine vessels a day are lying off of or alongside the pier, waiting to be loaded.

TRINIDAD LAKE ASPHALT PAVEMENT, WASHINGTON, D. C., VERMONT AVENUE,—ARLINGTON HOTEL. Laid in 1878.

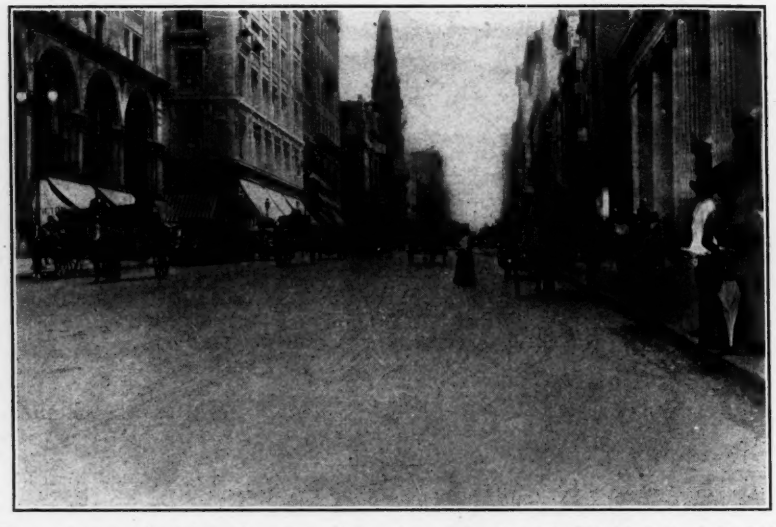
Much the same process is carried out at the Bermudez deposit, but the asphalt is carried from the lake to the shore of the river on a railway instead of by cableway. In either case, the crude material having been dumped into the hold of the vessel, runs together into a compact mass during the voyage to the United States. In consequence, it must be again picked out by laborers as it lies alongside the pier, and loaded into skips in which it is raised and again dumped into others, which are carried by a small railway to large storage bins holding several thousand tons, where it is again hoisted and dumped for storage until it is refined. Of course, in these bins it again runs together into a solid mass. As a supply is needed for refining, it is picked out and transferred to large rectangular tanks holding a hundred tons each, which are provided with gangs of pipe carrying steam at a pressure of 125 pounds and of about 325° F. This heat removes the water and melts the pitch.



SECTION OF VERMONT AVENUE PAVEMENT.

Agitation is provided by passing some of the live steam through the crude material while it is heating. When there is no further evolution of steam and the melted mass has become tranquil, it is drawn off from the bottom of the tanks into open cement barrels placed on flat cars. These are not filled at once, but are topped off after the first filling has cooled, so that there shall be no loss of material. The product obtained in this way is the refined asphalt of commerce, and is in shape for shipment to whatever point there may be demand for it.

It may be interesting to note that the amount of crude material shipped from Trinidad during recent years, has reached as high as 180,-



FIFTH AVENUE AT 34TH ST., NEW YORK CITY. Paved with Trinidad Asphalt 1897, photographed 1911.

000 tons per year, while that from the Bermudez deposits has reached as high as 47,000 tons but is rapidly increasing. The entire amount shipped from Trinidad since 1867 has reached three million tons, which would be equivalent to 180 million square yards of sheet asphalt pavement.

SERVICE TESTS OF TRINIDAD ASPHALT

Trinidad asphalt being for many years the only available supply of such material, it was the only one used in the early days of asphaltic highway construction in the United States. It has been subjected to the most varied environment with the most satisfactory results. There are in existence to-day three pavements which are worthy of consideration, as showing its capacity to meet different kinds of traffic and different climatic conditions.

A sheet asphalt pavement was laid in 1879 of Trinidad asphalt, on Vermont Avenue in Washington, between H and I Streets. This pavement is still in existence, and during that period has cost only in the neighborhood of ten cents a square yard, for maintenance for the entire period. It is apparently good to-day for ten or fifteen years more. This street is one of very moderate travel, delivery wagons and pleasure vehicles, and being very broad, over 100 feet, this is well distributed The pavement is typical of what Trinidad asphalt will do under such conditions for a long period of time.

Another striking piece of Trinidad sheet asphalt pavement is that on Fifth Avenue in New York, between 10th and 59th Streets. This was laid under the personal direction of the writer in 1896 and 1897, and has

VICTORIA EMBANKMENT, LONDON. Paved with Trinidad Lake Asphalt in 1906.

withstood the very heavy travel which Fifth Avenue carried in a most satisfactory way for fifteen years, the number of vehicles passing any one point, when the travel is the greatest, being at the rate of as high as 14,000 in ten hours. No other smooth surface pavement in any country has withstood the conditions existing on Fifth Avenue with an equally satisfactory result.

The third type of Trinidad sheet asphalt pavement is that found on the Victoria-Thames Embankment in London, the first portion of which was put down by the writer in 1906, upon old macadam and a course of Trinidad asphalt concrete. Much the larger portion of the embankment has since that time been paved with this same form of construction, other forms having been removed in the meantime as unsatisfactory and replaced by it. The surface of the Embankment is rarely dry from November to April, and it carries the very large traffic which pro-

ceeds from Westminster to the city. This serves as a striking evidence of the ability of Trinidad asphalt to resist dampness and to carry heavy travel in such a climate and in such a city as London, without deterioration.

I may further illustrate the uses of Trinidad and Bermudez asphalt by citing bituminous broken stone surfaces which have been constructed with these asphalts in Massachusetts and in the State of New York, which have been in use for at least three years, and have given the greatest satisfaction, the most striking feature of these roads being that the bituminous binding material is not drawn to the surface by the hot summer sun, but remains in the road where it is placed, with the greatest stability. Surfaces of this kind have furnished the most satisfactory service tests which are at present available, of a bituminous broken stone construction.

AN ECONOMIC INTERPRETATION OF PRESENT POLITICS

By Professor C. C. ARBUTHNOT
WESTERN RESERVE UNIVERSITY

ONE hesitates in taking the reader's time to call his attention to the fact that the present is an exceptional period of political unrest and anxiety over governmental policies touching certain public economic relationships. "Conservation," "graft," "the tariff," and "special privileges" have been talked about and about until the honest citizen who is trying to get a decent living for his family would be utterly weary if he were not so vitally interested in the results of the agitation. His interest in insurgency has become a demand for progression. There is determination in it.

The conservatives have felt that the whole hubbub is the result of unreasonable clamor, cheap reformers and low-priced magazines; that the people do not know when to leave well-enough alone, and that the wise policy is to adhere to the time-honored practises of the fathers until the storm blows by. On the other hand, great masses of the people are smarting under a sense of wrong and burdened by a feeling of oppression too great to be borne. They suspect they are playing the game of life with the cards stacked so that neither skill nor luck can be hoped to yield results favorable to themselves. The popular demand is for "fairness," "a square deal," and "equality of opportunity." The uneasy feeling prevails that the general public is losing something as well as the sense of personal injury. An exploitation of the many, collectively and individually, for the benefit of a few seems to be the evil of the day. Passionate reproaches, fierce denunciations, and tempestuous outbursts of feeling accompanied by determined action are aimed at the abuses. And yet no one can point to any fresh overt acts, or new public policies, or unusual legislation against which to protest. The subjects of the complaints are not the uncommon features, but the complaints themselves are. The economic and political phenomena assailed are time-honored, well-established heritages from the country's past that have come down to us from far enough back to be esteemed almost institutions characteristic of the republic. They do not need to be explained. It is the outcry against them that is to be accounted for, and the understanding is not far to seek. It is evident in view of our economic history.

Careful readers of history and students of social movements have

never seen the man on horseback appear in contented eras among satisfied people, notwithstanding all there is to be said for the powers of persuasion, the stir of audacity, and the impact of personality. The ponderous body politic can not be moved by word of mouth nor by the breath of eloquence. Merely preaching to it is foolishness. Internal pangs or external irritation are required to arouse activity. Demagogues are symptoms, agitators are weather cocks, and reformers are men who put themselves at the head of processions. When conditions are favorable for the start the opportunity for leadership arises and the self-seeking struggle with the public-spirited for the direction of the aroused energies. This guidance is of immense importance and no one should shut an eye to the danger of the glory-hunter's sway, nor lessen the credit due the reformer. But to understand the social situation in times of agitation there is need of separating in mind the more or less factitious elements from the fundamental forces at work. From this point of view speeches in legislative halls, on the stump, from the platform and the pulpit, the declarations of political parties and the editorials in the press, the harangues of public-square orators and the excited utterances of disputing citizens are not in the last analysis the outcome of the personal desire of a man or of a group, nor of a spontaneous moral tidal wave sweeping the community, nor of a resolute tugging at the ethical boot-straps of the country. Great national movements are products of fundamental forces in national life. The prophet who lifts his voice before these forces have begun to work dies in disappointment, or, if his message is too unpleasant to his contemporaries, he may achieve martyrdom. And if he has seen truly, succeeding generations may canonize him. The current of a people's thinking is glacial, slow to move; irresistible but largely determined by the contour of its bed. To the study of this formative influence one should address himself for an understanding of the greater changes that mark the history of public opinion.

At the close of the eighteenth century this nation began its career under unique conditions. A relatively small number of people possessed a vast territory over part of which they were sparsely living. Natural resources were boundless and wealth to be had for the taking. Acquisition was the watchword of the time. To open up the country was the economic ideal of the period. To this end were turned by common consent all the individual and collective energies available.

Among the most pressing needs of that day was that of capital for fixed investment in such improvements as better means of transportation. This was difficult to secure because the people were without great accumulations of wealth or the experience and instruments for readily collecting what was in existence. The machinery now in operation for promoting great enterprises and carrying through speculative ventures

is modern. If the Americans of the first years of the nineteenth century could have called forth an institution like the present Wall Street they would have regarded it as the greatest of blessings. As it was, one of the great accumulating agencies was the national government through its taxing power, especially in the form of customs duties. Besides and resting upon this was the public credit made strong by a ready and vigorous policy of paying public debts. The commonwealths shared this credit in a reflected form because leaders did not discriminate sharply between bonds of the states and obligations of the nation. Under such conditions of need for capital to develop the country economically and to bind it together politically, with an agency for supplying the want subject to popular will, it was inevitable that the people look to the government for aid in the construction of the desired public improvements.

Another resource of well-nigh unlimited extent lay in the hand of the federal government. When the British Crown granted charters to many of the colonies that later became parts of the original union, there was no exact knowledge of the lay of the land or the size of the interior of the continent. The terms of the grants were incompatible. The territories given overspread each other so that a division of the land among the independent states which came out of the revolutionary struggle was impossible. The problem was solved by turning over to the national government practically the whole of the area in question. The nation found itself in possession of a domain imperial in scope and possibilities.

With public credit and public land subject to the control of a people full of energy and ambition there could be but one result; their use with a lavish hand in furthering the interests of those who were developing the country's resources. Constitutional provisions, the reflection of current theory, limited the functions of government and we evolved a one-sided individualism whose chief tenet was state control in public benefactions to subjects and *laissez faire* in private use and enjoyment. Every citizen became an actual or potential beneficiary in the distribution of land and the extension of credit. The easy terms of the land laws threw open the widest opportunity for the acquisition of a farm to any one who cared to take it.

In order to bring these lands within range of the markets good transportation was necessary. The failure of the schemes for this purpose in most of the states in the thirties left a free field to corporate enterprise and every effort was made to encourage the construction of the means of carriage by private companies. The federal government gave lands to the states to be passed on to the railroad organizations as a stimulus. Other lands were given direct. The national credit was granted to new enterprises and second-mortgage bonds taken as security. Immense amounts

of wealth in lands, money and other forms were granted by smaller political units. This lavish generosity upon the part of governments had the warm support of the whole body of the people because the greater number of the individuals in the country were directly sharing in it or expected further indirect benefits from the development that would follow easy and cheap intercourse.

In this era of expansion the people thought in round numbers and on a grand scale. The superabundance of natural resources and the size of the anticipated results would have made any close scrutiny of the details of the transactions involved seem parsimonious cheeseparing, petty querulousness likely to interfere with the success of the transaction in hand and sure to delay the consummation unanimously wished. The popular will demanded that the thing be put through. All interests had to be conciliated and the ways greased if speed were to be attained. In thus doing business on wide margins and wholesale practically every one who helped the scheme forward felt a democratic right to participate in the benefits conferred. Legislators and administrators looked for an honorarium as a part of the exchange of courtesies incident to the negotiations connected with any public improvement of importance. The people at large were more interested in the execution of the proposed work than in the way it was carried out. Official parasitism on public improvements, graft, was regarded lightly as merely a sharing in the general distribution of the public largess. It was a commonplace; beneficial to the recipients and injurious to no one because, forsooth, it came out of the public abundance.

Development was the word to conjure with during most of our past and its magic opened men's minds to suggestion in every field of effort. Very early the creation of manufacturing industry became a desideratum. The infant industry needed protection. Notwithstanding the opposition of the South which then saw no promise of local benefit in the policy, the rest of the country enacted a tariff that took the edge off foreign competition if it did not entirely prevent it. Behind this barrier there came into existence factories and mills for the production of commodities as varied as the resources of the country would supply with raw material. The producers of this material rejoiced in the existence of a market immediately at hand and felt the benefit of the policy that the nation was more and more committing itself to carrying out. These new and flourishing manufactories were the nuclei of an urban population ready to purchase the products of farm and field: hence the agricultural interests were persuaded that the value of their lands was enhanced and their labor made profitable by the legislative act that brought the artisans and their families from Europe to the United States. Some palatable arguments allured many into thinking that the duties collected came from the foreigner, while others confident in the

strength of the expanding nation felt this was another of those beneficent acts of a government rich and solicitous for the well-being of all its citizens. The smoking stacks, the revolving wheels and the hum of the looms were referred to with pride as evidence of success in constructive legislation. As time went on faith in the possibility of legislating the country into prosperity continuously grew stronger and grants of protection became as common as grants of land. The favors were passed around by mutual consent and bargaining until customs duties were placed upon the importation of so many articles that precise knowledge of the effect of the whole system is beyond the grasp of even diligent students. The degree of industrial peace within our walls and prosperity in our palaces was commonly accepted evidence of the success of the American policy that silenced to most ears the doctrinaire objections of a discredited minority.

Parallel with national aid to industry were the grants and franchises given by local and municipal governments with a view to promoting public improvements within their jurisdictions. Street railways were essential to the development of towns and every inducement was offered to capital to lead it to go into their creation. The anticipated benefits were great, and the average citizen, who was busy trying to acquire his share of the collateral gains that were expected to accrue to the community, did not pay much attention to the terms of the contracts, while his representatives frequently exacted from the promoters of the new enterprises the customary informal fees to which in an era of acquisition they felt they were entitled. Fortunes were made all around them through the simple process of taking with governmental sanction and public approbation the lands, the bonds, the tariffs and the franchises that were to be had as part of the great scheme of continental development. There was nothing unusual in picking up these fragments when there were basketfuls being passed. The practise was common and hardly unclean.

From the conditions indicated in this brief analysis of our economic development it is easy to see how certain ideas came to prevail widely in the minds of Americans. At the bottom of our thinking has been the conception of a boundless productive continent to be parceled out by the government among its citizens. We have had the feeling that "the government" apart from the people as a body is wealthy. "Uncle Sam is rich enough to give us all a farm" is a popular expression of the notion. A professor in a well-known university has a stock question that he asks year after year concerning who shall meet the expense of a proposed scheme for social improvement, and the invariable answer is: "Let the government pay for it."

Along with the idea that the government possessed an all but inexhaustible store was the collateral feeling that doles should be given to

citizens from this property. The land grants made this familiar to the mass of the people and accredited it as a practise. Special grants to citizens, if they could be classified in any way as developmental in their outcome, were favored. Farms, franchises and tariffs were freely given and received. What are referred to now as "special privileges" were merely species of an approved genus.

When the ideas that the country was boundlessly rich and that it should be lavishly generous prevailed, it is not to be wondered at that the officials who were administering the division of the wealth should feel no hesitancy about taking toll of whatever passed through their hands. Graft was a normal collateral result of current practise and is to be distinguished from embezzlement or larceny. The officers were like men passing through a dripping orchard. To pluck and eat was to follow a natural impulse, easily yielded to when everybody was receiving according to their needs.

Out of these conditions of our first hundred years came the ethics of acquisition as a result of our method of exploiting a rich continent; a code which justified the accumulation of wealth by the process of taking it. This was normal and natural. The pertinent question now is, why has it become, or why is it becoming immoral?

A structure is no more stable than its foundation. The phase of public morals discussed here rested upon the fact that the people were carving up the public domain and trying to increase the value of their individual portions. When the good lands of the common heritage had passed from the government's control the general run of citizens had nothing to expect from the public directly. With the extension of the network of railways and other methods of communication over the country at large and the local areas as well, and after the rise of manufactures on a large scale, the prospect of further benefits from further opening of the country did not exist for the major portion of the people. When the populace can no longer look for immediate or collateral benefits of a private nature from governmental grants the policy of distribution is doomed in a democracy. Donations widely scattered may be approved, but if the range is narrowed they become evidences of favoritism and discrimination. As soon as the voters become conscious of the situation they will wipe out the remnants of the system. While "conservation" means both preservation of our natural resources in themselves and their future use for the people as a whole, the popular support behind the movement at present is in the nature of a demand that "landgrabbing" be stopped. What can no longer be done by all will not be permitted to any.

The swift growth of population has exhausted what once seemed to be a limitless territory. With the disappearance of good free lands falls the notion that the government of itself abounds in wealth. Men have

come to realize that they have been seeing darkly and now find themselves face to face with the fact that the government is no richer than the possibility of levying upon the income of its citizens. Favors granted by legislation are seen to mean that the hand of the tax and customs collector must be thrust into the pockets of the people to secure the necessary funds. As the realization of this simple truth becomes wider spread self-interest and the spirit of democratic equality rises against the practise. The vigorous opposition to ship subsidies in recent congresses are indicative of the new tendency. All grants by government, direct and indirect, are being more rigorously scrutinized, and none more so than that of protection against competition. Without enumerating the various influences that have produced the present chaos in practical politics, it is safe to say that while the tariff directly affects the cost of living, the present complaints against the recent legislation is due, not so much to an increased burden of duties as to a new sensitiveness to any duties that may seem to carry special benefit to a few at the expense of the many. The mind of the average citizen is reflecting the change that is taking place in his economic status. He no longer thinks of himself as a beneficiary in the development of the country due to the establishment and growth of great manufacturing businesses. He now sees that he is a consumer. When he used to pay out his money for protected articles his thoughts turned to the collateral gains that were expected from the country's expansion. Now he parts reluctantly with the price demanded because the only return is the goods received in exchange, and the additional cost due to the tariff comes to be regarded as an unwarranted exaction. There is no prospect that there will be any further expansion in which he can share. His economic interest lies in the present and forces him to buy his necessary commodities as cheaply as possible, so that the tariff becomes an object of hostility. The attitude to-day is not merely the result of an era of high prices due to other causes in addition to the tariff; it is not a temporary agitation stirred up by trouble-making partisans; it is a change in mind of the people due to a change in fundamental economic facts.

When the people begin to realize that they have to foot all the bills of the public service, directly or indirectly, and that there is no entity called "the government" upon which the burden can be laid; when it is clear that the government is simply themselves in their organized capacity, the institution of graft begins to totter. There arises a strong resolution to examine critically the expenditure of public funds when the private citizen feels that he is contributing them. Exactness and economy in the conduct of the common business and the administration of governmental affairs begins to be demanded from those officials who were formerly suffered to share in the distribution of the riches that figured as part of the public aid and encouragement given private individ-

uals with a view to social development. New occasions have taught new duties. When the idea of government in the rôle of Lady Bountiful is a thing of the past the practises that grew out of it and were more or less a part of it will have to go also. Doubtless there will always be peculation and rascality in the management of the people's affairs, but graft as an institution will cease to be overlooked and become disreputable.

In contrast with earlier practise the granting of franchises and other "special privileges" is being hedged about with limitations and restrictions unknown to our fathers. The new spirit of thrift in the body politic prevents the fast and loose dealing with valuable rights common in the flush days of exploitation. The worth of the privileges is better known now and it is actually greater. The need of conserving all the sources of public income is felt more and more so that there is a demand for *quid pro quo* when a grant is sought. The work of these companies in building up transportation, lighting and other general conveniences to their present stage has made communities more independent of them and the increase in demand for investments has strengthened the public position. More abundant capital needs opportunities for earning interest, while the body of the citizens have reaped all they can expect from the collateral increase in the value of their property that resulted from the pioneering done by the companies. They are ceasing to give away franchises because they do not need to do so any longer in order to secure the improvements and because the members of the community do not see a chance to participate in the resulting gains. The old methods are becoming immoral.

From what has been written it is perhaps apparent that the current agitation is not a reform movement that is leading to a departure from the error of our ways, but a conversion that is changing the whole of our attitude toward many public questions. The spread of the population, the division and occupation of the territory, the development of the country in transportation and manufactures have been part of the eager struggle for the treasures of a new continent in which grants of land, extensions of public credit, protective tariffs, franchises and tacit permission to graft have been prominent features. The ends sought have been accomplished and the means that were formerly reputable because commonly shared are now condemned. They can no longer be general in their effect either directly or indirectly. When they are confined to a few they cease to be benefits and become favors; and favors are odious in a democracy. The old policies are passing away because the old economic basis upon which they rested and from which they arose has passed away. The enemies of the old order have come in like a flood, not because of a particularly high moral tidal wave but because the shore has subsided. What is going under water now is going to stay

under. These sunken rocks will wreck many a politician's bark in the next few years. Until the change has become definite and the new coast has been charted there will be no safety on political seas. The present confusion of mind makes it difficult for constituents and representatives to understand each other. Chance and whim will determine more than a few public careers before the transition is gone through.

The story of this phase of our economic activity can be compressed into a few sentences. An energetic people possessed with the spirit of equality, and working on an undeveloped domain, flourished forth in a democratic era of acquisition, exploiting natural resources and each other. Now that the natural wealth has been so largely appropriated, it is no longer possible for the majority of the people to continue their former practises, and they have been demanding through a few of their representatives that the minority also cease. This was insurgency.

When the new spirit began to possess the people they endeavored to enact legislation or repeal laws and reorganize administration with a view to abolishing the antiquated institutions and practises that had become odious. They found, however, that the specialization of function had gone so far that there had grown up a governing class of politicians, office holders and administrators fairly distinct from the mass of the citizens. This caste removed from the pressure of new conditions that were changing the lives and thinking of the people in general is dominated by the traditions, customs and practises of an earlier period. The code of ethics of the era of acquisition still obtains among the governing group because the members of this group have not been exposed to the influences to which the common people have been subjected. The representatives of the people now in office represent the people of earlier generations—not their contemporaries. The leaders are in the rear, and persist in staying there. This inability to catch step, this moral inertia, is leading an increasing number of people to doubt the workableness of representative government. When a candidate is elected he enters into the governing group: the atmosphere he breathes is fifty years old: he is soon behind the times. He does what was formerly acceptable, but is no longer so. He does not represent his constituents, for the simple reason that they do not look upon the public affairs as their fathers did. The constituents have changed—the representatives have remained the same.

The extreme difficulty of bringing up to date the machinery of government as at present operated is what is behind the movement for the initiative and referendum that has enrolled within its ranks great numbers of men who have hitherto regarded the proposals of direct legislation as impracticable, cumbersome and out of the question in political units of any great size. Their old objections are as valid as ever they were for a situation in which the people and their representatives are

morally synchronous. But that is emphatically not the present condition. The period of transition has made it necessary to shorten the pendulum of representative government to make it move as fast as the people wish it to go. The voters have repeatedly tried to set the clock forward by electing new men to office, but the new men after election soon fell into the old swing. Direct legislation seems to be the only way to keep those elected to represent the present from falling into the practises of those who represented the past. Its strength as a political issue lies here. Its function will doubtless be temporary. When it has done its work, it will have made government really representative again and itself doubtless fall into disuse.

Looking at the initiative and referendum thus in the best light leaves one, however, with a decided feeling that the agitation for them is pretty much a "talking point" in the process of developing public interest in changing the methods of public business, very serviceable, of course, to the candidates who are conspicuously eager to "trust the people." As a matter of fact, direct legislation to be successful, will need keen and intelligent public interest. Such an interest would result in a wiser choice of more responsive representatives and accomplish the same results with less strain on the electorate. The disinterested advocates of changes in the mechanism of government in this case are overemphasizing the form to the neglect of the spirit. The new attitude of the public mind will soon be sufficiently strong to secure complete expression in government with or without the aid or hindrance of direct legislation.

No one may expect the new weapons to destroy quickly the old institutions that have become abuses. They are too well rooted to die without a struggle: but in time they will die. There is no longer that upon which they can live.

HELPS TO STUDYING

By Professor JOSEPH W. RICHARDS, Ph.D.
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TO study means to concentrate the mind and attention on a subject, and to keep it there until the difficulties are mastered and the subject understood.

Aside from the philosophical principles involved in absorption of the mind upon one idea or in one line of thought, there are certain physical or even mechanical aids to this end which are well to know. The writer is not skilled in mental philosophy, but has observed certain simple facts pertinent to the subject of studying which may assist others, and therefore he takes this opportunity of setting them forth. Any one can easily determine for himself how true they are, or whether they apply to him personally or not.

The first enemy to concentration is a roving attention, the coming up into the mind of thoughts or recollections foreign to the matter being studied. I have seen a student, supposedly hard at his task, fix his eyes abstractedly on a corner of the room and think for five or ten minutes of something else, then suddenly recollect that his lesson was not being thus mastered, and with an effort, and perhaps a yawn, bring his attention back to his book. Such a youth is in a pretty bad way, as far as study is concerned, yet the remedy is simple, if he will apply it. I have spoken of the *effort* to bring his attention back to the book; let him, as soon as he feels the inclination to let his attention wander from the book, make the same effort to *keep* it there, and he will nip the evil in the bud. It is no harder, surely, to hold the attention, to prevent it wandering, than it is to bring it back after it has wandered. But, said youth may say "That is fearfully hard work"; to which we reply that study is admittedly hard work, but the hardest part of it is just this effort to keep the mind steadily on the subject studied. What we mean is, that the student must make a hard, determined and earnest fight to keep his attention from roving, that he must fetch his mind back to the straight road by a vigorous mental effort, as soon as he finds it tending to stray, just as a skilful driver reins his horse back into the highway the instant he sees it turn towards a byway. Keep your mind and its activity well in hand, be its master and compel it to do what you want it to do. Such is mental power.

The next enemy is noise or interruption of any kind, be it even so melodious as the finest music. It acts, of course, by distracting the at-

tention. Drafts of air fluttering a curtain, a door banging, heavy or rapid foot-steps, whistling, singing; above all talking. Here is where students can help each other, by gentlemanly consideration for each other. One's ears are always "at attention" when studying, and everything heard distracts attention to some degree; the only exception is a steady drone or buzz, which becomes unnoticed because of its steady continuance. It is impossible, we admit, to provide absolute silence for the student, but fellow students should minimize as far as in their power all disturbing noises in their houses or dormitories, and the boor who insists on "disturbing the peace" unnecessarily should be given his walking papers; he is the common enemy.

Another cause of distraction is a common one in American student life, and exists just because of his abundance of creature comforts. This is the proneness of the student, or possibly of his well-meaning but misguided mother or sisters, to make his room *attractive* by means of pictures, by souvenirs on the walls and tables, by bric-à-brac of various kinds scattered about. When to this are added the various mementos of jubilant class-dinners, rushes, midnight raids on street signs, perhaps even a souvenir of a night in jail, need I say how these *distract* the student's attention from his book. One roving glance, and the family group reminds him of home, that class picture reminds him of his comrades, the flaming poster reminds him of the excitement of his freshman experiences, the policeman's club reminds him of the street row when on a sign-stealing expedition, etc. Need it be said, that, when this unfortunate wight is trying to study, he does not need to be reminded of these things as an aid to concentration, that souvenirs do not help him to keep his attention on his book, and that the more *attractive* his room is the more it *distracts* his attention. I do not confound attractiveness with comfort; the latter the student should have, the more the better, but the comforts should be real, unobtrusive ones.

I am simply protesting against that misguided custom which often regards students' rooms as *olla podrida,* museums of bric-à-brac, proper depositories of any and every object which can remind the student of the glorious life he is leading—and which are all common enemies, to a smaller or greater degree, to that concentration of mind which he most needs, as a student, to cultivate and to possess.

However, the room must have something in it, the walls should not be those of a bare attic, let us admit, and therefore, what is the student to do, when studying? On this head, we have two suggestions to make, which have been tried and found effective. First, when studying by daylight, have the table near the window, so that the light is sideways, and one's back is partly towards the "attractive" room. If the window gives on a busy street, have the lower half covered by a translucent curtain, to keep the attention from being distracted by happenings outside. If the window looks out on a quiet neighborhood, or

especially on a country scene, the curtain is unnecessary. The best situation is where there is a rather extensive view from the window, for then the student can from time to time rest his eyes, wearied by their short focus on the book, by letting them focus on the distance, the farther away the better, without there being any moving factors in the scene to particularly claim attention. Under these circumstances, his eyes being rested, but his attention not caught, the student's mind will often go back naturally to what he is studying, and will reflect on the points just learned. Given such a window, with such a view, and absence of unnecessary noise, and the student should do good work in daylight.

At night the conditions are very different. Artificial light must be used, and of what kind and how placed is all-important. The writer may have had limited experience in some of these regards, but the following are the results of his observation, and are given for what they are worth:

First, the illumination should not be general. The only matters concerned are the student and the book, and as the student will get his illumination from the book, it is only the proper lighting of the latter which is to be considered. A lighting scheme which lights the whole room is worse than useless, it is undesirable. The better the book is lighted and the more the rest of the room is in comparative darkness, the easier it is for the student to keep his attention fixed on the book and the less is he distracted by seeing the other things in the room. Is it not an old trick of the artist, to focus and hold the attention by a brilliantly-colored "center" (such as the child's face in Correggio's "Holy Night"), in the midst of an obscure back-ground? Therefore, applying common sense as well as artistic perception, illuminate the book to be studied as much as is necessary, and the rest of the room as little as is necessary. By so doing, concentration on the book is wonderfully assisted.

Second, place the light in front and preferably to the left. We are not here speaking of how to sit in an easy chair and read a novel most comfortably, with the light coming over one's shoulder; but we speak of the student with a book which needs mastering, probably with pencil in hand and a pad of paper alongside. Such requires the student sitting squarely at a table, with his paper and pencil ready for action. In this case, the light should be close, not over three feet away from the book, better at half that distance, so that practically only a small circle is illuminated, with the book nearly in its center. If placed directly in front, the glaze on the paper may easily interfere with reading; and if writing (with the right hand), placing the lamp to the right will be likewise annoying because of the reflection from the glaze. The best position is for the light to be to the left a few inches, as far forward as the top of the book or paper, and no higher than the eyes. A green

shade over the light, enamel-white inside, is the best. A white shade lights up the room in general too much, and necessitates the student wearing a green eye-shade on his "noble brow." The latter is uncomfortable, and quite unnecessary if put over the light instead of over his eyes.

Third, a student oil-lamp gives the most satisfactory illumination, if kept in good order. The wick should be kept free from excrescences, so that it always gives its proper, steady, mellow, yellow light. The ordinary gas burner flickers too much, the electric light is steadier but can not be regulated, the Welsbach-mantle light is too brilliant if turned on full and too variable if turned down.

Fourth—and most important of all—turn the light down low, and then turn it down some more! Given the right kind of light, the student lamp, one third to one half its full illuminating power, is all that is necessary or desirable. The reason is highly important, for reading easily and for the welfare of the eyes, and it is this: We see the print by contrast of nearly black against nearly white; with no illumination there is no contrast; as the illumination increases the contrast becomes better and reading is easier. At a certain point, the contrast is greatest and reading is easiest. But it is an entirely erroneous idea that the greater the illumination the greater the ease of reading. Hold the page directly in the sunlight; can you read it easier? There is a certain amount of illumination at which the contrast of print against paper is a maximum and where reading is easiest, with least fatigue to the eyes. This point varies for different-sized prints, for different inks, for differently surfaced papers and for different tints of papers. The point can be readily and easily determined in a fraction of a minute, in any particular case, by any one wishing to find it, by simply turning the light slowly up, keeping the eyes on the book, and noting the *least* light at which the print is clearly seen and read without sensible effort. This is the point at which you can read that book the longest without strain or fatigue; it will usually be found at about one half or less of the illumination ordinarily used. (I will not speak of the saving in "midnight" oil thereby attained; the saving in "eyes" is more important.) One can often read and study for hours with this light, whereas a brighter light would really make reading more difficult and tire out the eyes in a fraction of the time.

The effect of heeding and using the above principle is that eye-fatigue is minimized and thus study is done with less distraction from this cause. The point explained is the point of maximum comfort, and, therefore, of maximum efficiency. With only the book illuminated, and lighted just to the point of maximum comfort, all other objects in the room in semi-darkness, and the student anxious to study, let us leave him to himself, to see what he can make out of the situation.

BEES WHICH VISIT ONLY ONE SPECIES OF FLOWER

By JOHN H. LOVELL
WALDOBORO, MAINE

ONE warm afternoon on the twentieth of July I was collecting insects from a boat on the Medomac River. A thunder-shower was coming up in the northwest. The air was very still and in that peculiar condition which precedes an electric storm. At such times insects are very sluggish and seek shelter against the approaching tempest. The silence was broken only by the rumbling peals of the distant thunder, following the bright flashes of lightning, which illumined the dark thunder-heads of the advancing clouds. It became necessary for me to hasten homeward. To my surprise I noticed on almost every one of the violet-blue spikes of the pickerel-weed (*Pontederia cordata*), a species of water hyacinth, which in countless numbers fringed the winding stream on both sides, one to several small bees. They had crept within the bilabiate flowers as far as possible, and were evidently intending to await there the passing of the storm. They were so inactive that no net was required, and I could easily knock them off into the cyanide jar. I collected about forty specimens and could have easily collected hundreds. This phenomenon has never been repeated to my knowledge.

On examination the bee proved to be *Halictoides novae-angliæ,* or the pickerel-weed bee. Every season when the pickerel-weed is in bloom I find both sexes of this bee on its flowers, and though I have carefully observed the visitors to many other plants in this locality I have never met with it elsewhere. Apparently in this region it never visits any other flower—it is a monotropic bee. When a female bee in gathering pollen for brood-rearing visits but one kind of flower it is termed a monotropic bee, or if only a few allied species an oligotropic bee; but if it visits many flowers it is called a polytropic bee. These terms were first proposed by Dr. Loew, and signify adapted to one, few or many flowers.

It is impossible not to feel some curiosity as to why this little bee restricts its visits to the inflorescence of the pickerel-weed. Notice that it flies only at the season of the year when this aquatic plant is in bloom, and that it finds within the perianth both food and shelter. Very likely its nests are built not far away. The flowers of the pickerel-weed strongly attract insects by their great numbers, bright hues, pleasant fragrance and abundant nectar and pollen; and consequently are sought

out by many bees, flies and butterflies. Bumblebees especially delight in these blossoms, which they visit with astonishing rapidity—*Bombus consimilis* making about seventy visits per minute. On the middle lobe of the upper lip there are two bright yellow spots, which tell of the presence and guide to the exact location of the nectar concealed within the tube of the perianth. When the pickerel-weed bee makes its appearance about the middle of July, there is no other flower in southern Maine which can offer it so many inducements as the pickerel-weed. But let us look farther and see if there are any other bees, which behave in a similar manner.

In the quiet bays of the river, floating upon the surface of the water, bloom the yellow water lilies (*Nymphæa advena*).

> Again the wild cow-lily floats
> Her golden-freighted, tented boats,
> O'ershadowed by the whispering reed,
> And purple plumes of pickerel-weed.

The flower is securely anchored to the bottom of the stream by a long stem. At first the opening in the bud is no larger than a bee's body, and the chamber within offers a dry and snug shelter amid the waves. It may truly be called a haven of refuge. Directly below the entrance is a broad, many-rayed, crown-shaped stigma, as in the poppy. The petals are thick, wedge-shaped bodies which are orange-yellow on the outer side near the top, where they freely secrete nectar. Under a microscope both large and minute drops can readily be seen. The stamens are indefinite in number; and reveling in the pollen, their bodies completely covered, there is a large and lively company of small flies called *Hilara atra.* Less common are two beetles, *Donacia piscatrix* and *Donacia rufa*; but what chiefly interests us is a small bee, *Halictus nelumbonis,* or the water-lily bee. This bee in this locality is never found on any other flower, but elsewhere it is met with on other species of the water-lily family, or Nymphæaceæ. It is an oligotropic bee, and the only species of the great genus *Halictus* that is known to behave in this way.

But in *Andrena* this is a common phenomenon, for instance, in Washington County, Wisconsin, according to Dr. Graenicher, twenty-four of the forty-seven indigenous species of *Andrena* are oligotropic. This is the largest genus of North American bees. They are sometimes called ground-bees, since they build branched tunnels eight to ten inches deep in the soil of sandy pastures and hillsides. A part of the species are vernal or fly in springtime, while a part are autumnal and fly only in autumn. They provision their cells with balls of "bee-bread," about the size of a garden-pea, composed of pollen moistened with nectar. An egg is laid on the top of the mass of bee-bread, and the cell is then closed.

The bright yellow staminate aments of the pussy-willow (*Salix*

discolor) are great favorites of vernal species of *Andrena,* whence Smith calls them "harbingers of spring." The pussy-willows bloom in northern New England during the latter part of April, and their bright yellow aments are very pleasing objects in the cold gray landscape. They are very attractive to a varied company of insects, as honey-bees, bumblebees, flies, butterflies and beetles. It is a busy scene and one which the naturalist can never tire of watching; but it is not one of unmixed happiness, for little tragedies take place before our eyes. Among those which come to sip the nectar are little dance-flies (Empididæ), and not infrequently they are seized and carried away bodily by black robber ants, which roam everywhere. Honey-bees and many species of *Andrena* come in great numbers to procure pollen for brood-rearing. A part of the Andrenid bees gather only a portion of the pollen they require from the willows and the balance from the maples, plums, cornels and *Viburnums;* but there are four species (*A. illinoiensis, A. mariæ, A. erythrogaster* and *A. moesta*), which get their whole supply from this genus of plants. Of the autumnal flying species of *Andrena* there are five (*A. canadensis, A. nubecula, A. solidaginis, A. hirticincta* and *A. asteris*), which I have collected only on the flowers of the Compositæ, or aster family; and four of these bees confine their visits very largely to the golden-rods. In both *Salix* and *Solidago* the inflorescence offers an ample supply of nectar and pollen and there is little temptation for Andrenid bees to go elsewhere, when their time of flight coincides with the period of blooming of these two genera.

But in other localities *Andrena erigeniæ* is reported to be a monotropic visitor of the spring beauty (*Claytonia virginica*), *Andrena violæ* of the violet (*Viola cucullata*), *Andrena geranii maculata* of the wild geranium (*Geranium maculatum*), *Andrena fragariana* of the strawberry (*Fragaria virginica*) and *Andrena parnassiæ* of *Parnassia caroliniana.* It is not so easy to explain the behavior of these latter bees. It seems very remarkable that they should restrict their visits so closely to the flowers mentioned.

Macropis ciliata, or the loosestrife bee, usually gets its pollen from the flowers of the common loosestrife (*Lysimachia vulgaris*); while many species of *Panurginus* are taken only on the inflorescence of the Compositæ.

But this habit of visiting only one kind of flower is perhaps better illustrated by *Perdita* than by any other genus of bees. Only one species of *Perdita* is found in Maine; but in the western states some 90 species occur, of which about forty live in the arid regions of New Mexico. In Maine *Perdita octomaculata* is found almost exclusively on the panicles of *Solidago juncea,* the earliest blooming of the golden-rods; and I have never met with it on any other species except in one instance. In New Mexico two species of *Perdita* are found on the willows, *Perdita zebrata* visits only *Cleome serrulata, Perdita crotonis*

visits *Croton texensis, Perdita albipennis* visits *Helianthus annuus* (sunflower), and *Perdita senecionis* visits *Senecio Douglasii.* "It may be laid down as a rule," says Professor Cockerell, "that each species of *Perdita* visits normally but one species of flower, but occasionally specimens may be found on flowers to which normally they do not belong." But in many instances several species of *Perdita* frequent the same flower. The bees of this genus are small forms very frequently marked with bright yellow.

Many species of *Colletes, Epeolus* and *Melissodes* visit almost exclusively the flowers of the Compositæ, as the thistles, golden-rods and asters. *Xenoglossa pruinosa* confines itself to *Cucurbita pepo* or the common field pumpkin; while *Megachile campanulæ,* one of the leaf-cutting bees, is a monotropic visitor of the bellflower *Campanula americana.* Many other instances are recorded, and many more will no doubt be discovered when our bee fauna is better known.

This is certainly a very singular habit on the part of bees, and one which could hardly have been foreseen. On the contrary, it is generally supposed that bees fly about sipping sweets indiscriminately, as they are so commonly represented by the poets.

> He woos the Poppy and weds the Peach,
> Inveigles Daffodilly,
> And then like a tramp abandons each
> For the gorgeous Canada Lily.

It is really getting unsafe for poets to write about nature in their old, haphazard way, trusting chiefly to their imagination as a guide. Fancy can supply nothing half so wonderful as the true facts about flowers and insects. Let us consider what theories naturalists have advanced to explain this curious habit!

In Kerner's day only a few oligotropic bees were known, and he believed that they gave the preference to certain flowers because they found their odors so highly attractive. But it is incredible that so many bees should be dominated in their flight to such an extent by various floral odors, and besides they not infrequently visit several flowers which differ in scent. No doubt, though, bees have their preferences in odors and nectars, and probably they prefer pollen that has a roughened or spined surface to that which is smooth.

A more probable explanation claims that female oligotropic bees have adopted this method of visiting flowers to avoid competition in gathering pollen for brood-rearing. This theory is only partially satisfactory and certainly is not always applicable, even assuming that such a partition is beneficial or required. The four species of *Andrena,* which in this locality visit exclusively the willows, do not thus avoid competition nor do they thus benefit other bees. The willow aments have pollen enough for all comers. In this particular case this habit seems to have arisen because it was advantageous to these bees to re-

strict their visits to flowers so abundantly supplied with pollen and nectar, combined with their early and short time of flight, which lasts only about a month, and perhaps also to their nesting near these shrubs. Where bees fly only during the latter part of the season it seems very natural for them to restrict their visits to the Compositæ. These flowers, as in the case of the golden-rods and thistles, are very common, contain ample food supplies and are easy to visit. They are actuated not by the need or desire of avoiding competition, but by the same motives which lead honey-bees to visit the white clover exclusively while it is in bloom.

The oligotropic habit is not beneficial to flowers, it concerns the bees alone. The oligotropic bees are almost without exception solitary forms, to which there are no flowers specially adapted. The social bees, as a rule, visit a great variety of flowers, though in Europe it is stated that there is a bumblebee (*Bombus gerstaeckeri*) which visits a single species of monkshood (*Aconitum lycoctonum*). Here, of course, the adaptations are mutual. This mode of flight, however, has not in general been determined by floral adaptations. Certain species of bees have become satellites of certain flowers because of the advantage thus gained for themselves, and partly also perhaps as the result of habit. Just as there are fly-flowers, butterfly-flowers and bumblebee-flowers, so, on the other hand, there are willow-bees, golden-rod bees, a pickerel-weed bee, a loosestrife bee, a violet bee and a strawberry bee.

Two most important influences are the season of the year and the length of time the bee is on the wing. It is clear that bees which fly only in spring or autumn for about a month have not a great choice of flowers; and, of course, we never look for autumnal bees on spring flowers. Usually the length of time an oligotropic bee flies and the flower it visits is in bloom are about the same. The honey-bee is practically a monotropic bee at certain seasons of the year. While the basswood and white clover are in bloom the honey-bee visits these flowers almost exclusively. Again in the fall in Maine it confines its attention solely to the golden-rods. In California at times it collects nectar exclusively from the sages; in Michigan from the willow-herb, and in other regions from other plants. If from any one of these plants it also obtained its supply of pollen and was on the wing only while it was in bloom, it would be regarded as a monotropic bee in the strict sense of the word. That it exhibits a strong tendency, when collecting pollen, to be constant to one plant species is well known; and the little packets of pollen it brings into the hive seldom consist of two kinds of pollen. But, when a bee flies from spring till fall and requires a large amount of stores, it is evident that it can never become oligotropic.

Another important factor is the small size of many oligotropic bees. This is true of *Prosopis nelumbonis, Halictus nelumbonis,* and many

species of *Panurginus, Perdita* and *Andrena.* These bees have a weak flight and are not fitted to travel long distances. It is known that in some instances they build their nests near the flowers they visit. Probably this generally true. The medium-sized oligotropic bees, belonging to the genera *Colletes, Epeolus* and *Melissodes,* fly in the fall and visit chiefly the Compositæ, a family which offers a wide choice of flowers. It is not always easy here to draw the line between an oligotropic and a polytropic bee.

There are still in existence many intermediate stages betwe n monotropic, oligotropic and polytropic bees. While many bees visit a great variety of flowers, others visit only one family, as the Compositæ or Nymphæaceæ, others only a single genus, as *Salix,* and others only a single species, as the violet, strawberry or spring-beauty. Many exceptions no doubt occur and will be recorded when the habits of these bees have been more carefully observed. For instance, I have often seen the loosestrife bee on the umbels of the prickly sarsaparilla. It is evident that if a monotropic bee extends into a region, where the flower it visits elsewhere does not occur, it must of necessity visit other flowers. Dr. Graenicher writes me that the pickerel-weed bee (*Halictoides novæ-angliæ*) is found in Wisconsin; but the pickerel-weed does not flourish in the same locality, and so this bee is compelled to visit the blossoms of other plants. Evidently this habit did not originally exist among bees, but has gradually been acquired.

We may sum up the matter as follows. All bees including the honey-bee show a strong tendency in collecting both nectar and pollen to be constant to one species of flower. This is manifestly for the advantage of both insects and flowers. In the case of a number of bees flying for only a small part of the season this habit has become so specialized that they visit only one or a few allied species of flowers, which offer an abundance of pollen and nectar. Primarily it seems to be the direct advantage gained rather than the avoidance of competition that has led to the rise of the oligotropic habit. As the honey-bee for a time restricts its visits to the white clover, so in like manner a monotropic bee visits but a single kind of flower. But in the former case the bee flies throughout the whole season, but in the latter when the flower fades the bee's period of flight is over.

The idiosyncrasies of bees in visiting flowers present many remarkable peculiarities, and undoubtedly offer an attractive field for observation. There are certain bees, which though they are not oligotropic obtain the larger part of their supplies from comparatively few flowers, as the plums, thornbushes, cornels and *Viburnums.* In this locality one of the leaf-cutting bees (*Megachile melanophæa*) shows a decided preference for the purple vetch (*Vicia cracca*), and if I desired a specimen I should look for it on the blossoms of this plant. As the parasitic bees do not provide stores for their brood and seek nectar for themselves alone, they show little preference for special flowers. For a simi-

lar reason the males of any species of bee may not visit the same flowers as the females, though the attraction of the female may largely influence their course, in which respect they exhibit quite human sentiments. It would, of course, be in vain to look for the males of *Bombus* and *Halictus* on the flowers of spring, since they do not appear until mid-summer. In the case of dicœcious plants, or plants in which the sexes are on different individuals, the bees visiting the staminate flowers are more numerous and are sometimes widely different from those visiting the pistillate. The common sumach is a good example. Indeed the bees visiting a flower in its early stages may differ from those visiting it in its later stages. Again the visitors to a flower may differ, both in number and kind, in different seasons.

The depth at which the nectar is concealed is another most important factor in controlling the visits of bees. In some flowers it is fully exposed on a flat surface where it is accessible to all insects; in others it is at the bottom of a slender tube, where it can be reached only by the larger moths. The familiar fable of the crane and the fox is constantly illustrated among flowers. As a matter of fact, bumblebees and butterflies avoid rotate, flat flowers containing little nectar, since their long tongues do not permit them to suck easily on such a surface. On the other hand, it would be useless to look for the smaller bees with short tongues on the larkspurs and clovers, for the nectar is quite beyond their reach.

As we take our leave of the oligotropic bees it may be inquired if there are any other insects, which visit only one species of flower. There are many others, especially among butterflies and moths. The flag beetle (*Mononychus vulpeculus*) passes its entire life on the blue flag (*Iris versicolor*). This small weevil feeds both on the pollen and nectar and sometimes gnaws the flower-leaves badly. The eggs are laid in the young seed capsules, where the larvæ feed on the ripening seeds. Both the adult beetles and larvæ are supported at the expense of the blue flag. The legitimate pollinators are bees and while the flag beetle may rarely effect pollination it does far more harm than good. This symbiotic relation is a benefit to the insect, but an injuiry to the plant.

Two slender metallic-hued beetles (*Donacia rufa* and *Donacia piscatrix*) find very comfortable quarters within the flowers of the yellow water lily, where they idle away much time drinking nectar and eating pollen. They lay their eggs on the leaves and the larvæ burrow in the stems. As in the case of the flag beetle this arrangement is evidently more to the advantage of the beetles than of the plants.

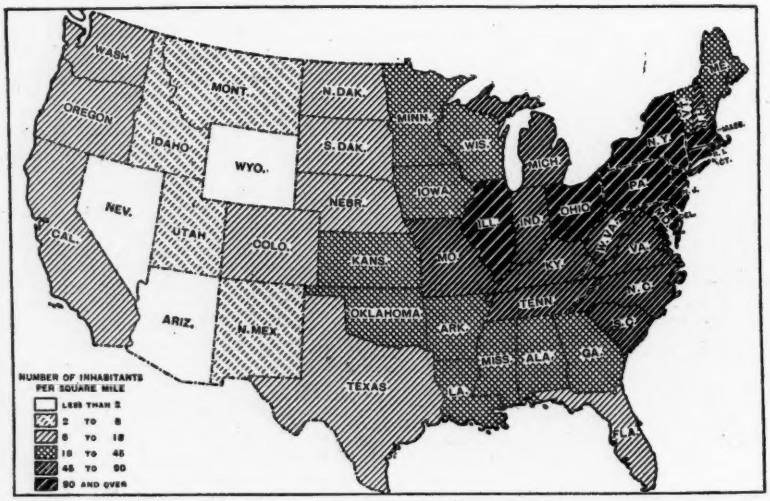
The night-blooming yucca, or Spanish bayonet, which flourishes throughout the southern states, is pollinated exclusively by a small nocturnal moth. The larvæ of the moth live in the seed-capsules. Thus both plant and moth are reciprocally dependent on each other, and the destruction of the one would be followed by the disappearance of the other. But in most instances the insect receives the greater benefit.

THE PROGRESS OF SCIENCE

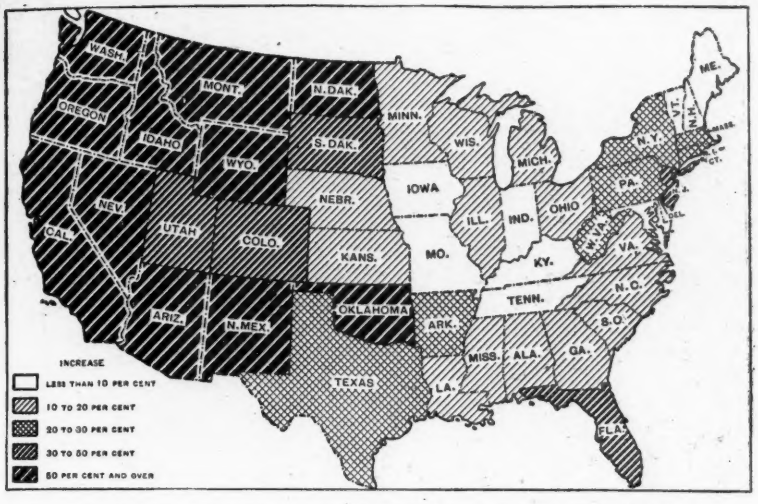
THE POPULATION OF THE UNITED STATES IN 1910

THE Bureau of the Census has now issued a bulletin giving the official figures of the thirteenth census, preliminary statements of which have from time to time been made public. The population of the United States was 93,402,151, of which 1,429,885 belongs to the non-contiguous territory of Alaska, Hawaii and Porto Rico and persons in the military and naval service stationed abroad. There are still to be added the inhabitants of the outlying possessions of the United States —some eight millions—nearly all in the Philippine Islands. The percentage of increase from the preceding census is 21, being three tenths of a per cent. larger than for the preceding decade. The population of the United States shows an increase of about one third during each of the seven decades from 1790 to 1860, of about one fourth during the three decades from 1860 to 1890 and of about one fifth during each of the last two decades. Thus while the increase in population over the preceding census continually increases, the percentage of increase becomes continually less, and there is no reason to suppose that the population will increase indefinitely. Indeed, if it were not for foreign immigrants and their larger families, the increment of increase of the population would be very small. It should, however, be added that there are those who hold that the native population would increase more rapidly if it were not for the large immigration.

The density of population and the increase of population, as shown on the accompanying maps, are very unequally distributed over the United States. There are ten states in which there were in 1910 a population per square mile of more than one hundred. Rhode Island with 508, and Massachusetts with 418 are the most densely popu-



NUMBER AND DISTRIBUTION OF POPULATION PER SQUARE MILE BY STATES, 1910.



PER CENT. OF INCREASE IN TOTAL POPULATION BY STATES, 1900–1910.

lated states, followed in order by New Jersey, Connecticut, New York, Pennsylvania, Maryland, Ohio, Delaware and Illinois. The least density of population is in the mountain states, Nevada with less than one inhabitant to the square mile ranking the lowest, followed by Wyoming and Arizona. The largest percentages of increase are shown by the mountain and Pacific states, Washington leading with an increase of 120 per cent., followed by Oklahoma and Idaho. As has already been widely noted, Iowa shows an actual decrease in population. The states of Missouri and Indiana show very moderate increases; the rural New England states also show small increases of from four to seven per cent. The increase in New York is 25 per cent. and in Pennsylvania 22 per cent.

The urban population, which includes those residing in cities of 2,500 inhabitants or more, has increased 35 per cent., and the rural population 11 per cent., seven tenths of the sixteen million increase being in the cities. The urban population is now 46 per cent. of the total population, whereas in 1880 it was 29 per cent. The three cities—New York, Chicago and Philadelphia—having a population of more than one million, show thirty-two per cent. increase, while five cities, having a population of 500,000 to one million, show an increase of only 20 per cent. The cities—90 in number—having a population of 50,000 to 250,000 show the largest percentage of increase, namely, 41 per cent. In New England and the Atlantic states about three quarters of the people live in the cities.

THE ERADICATION OF HOOK-WORM DISEASE

THE second annual report of the Rockefeller Sanitary Commission tells the story of a dramatic achievement of modern sanitary medicine. It will be remembered that the existence of hookworm disease in the south was not suspected until recently. It has now been found to be extremely prevalent. In the infection survey of the commission 87 counties were covered, 37,267 children examined, and the percentage of infection by counties was found to range from 2.5 to 90.2 per cent. In some schools practically every child was infected, and a large percentage of all children were unable to attend school. The disease is particularly disastrous in its consequences, for though not ordinarily fatal, like malaria it prevents

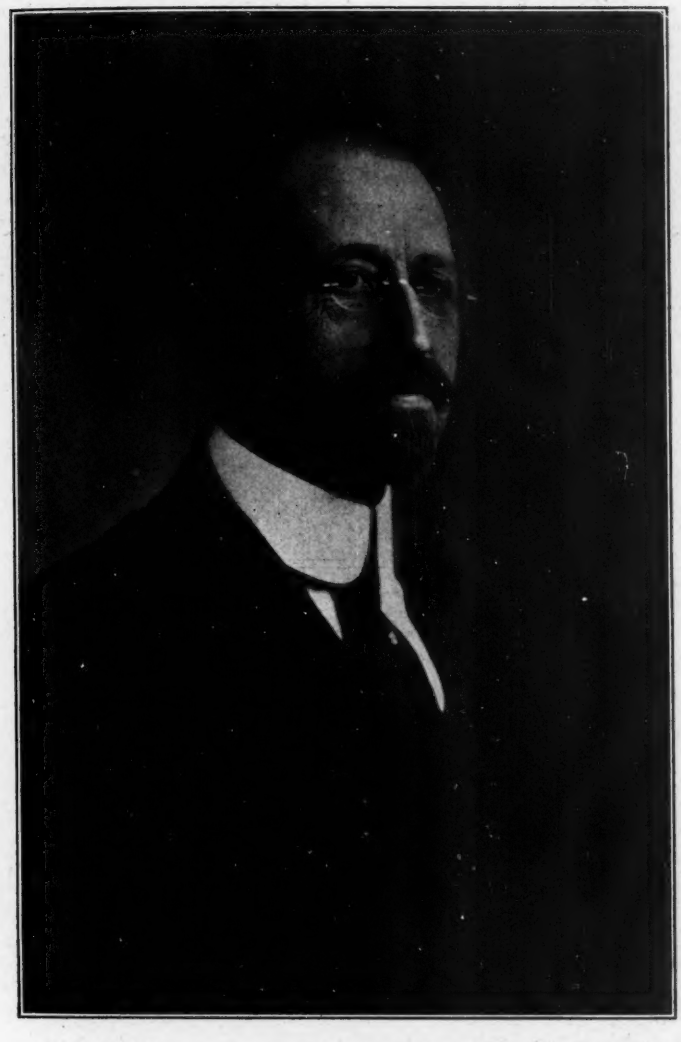
DISPENSARY GROUP AT PUBLIC SCHOOL BUILDING, FAIRMON, ROBISON COUNTY, N. C., July, 1911. Treated at the place on that day, 187.

the individual from doing his ordinary work, reducing, it is said, his efficiency to less than half. A good part of the inefficiency, laziness and lack of enterprise of the white people of the south is attributable to the infection. It is further a disease which is both curable and preventable, and it is in such a case that medicine and hygiene have their great opportunity.

Some 75,000 persons were treated at the initiative of the commission, and much was accomplished by spreading knowledge as to the means of preventing soil pollution. Indirectly the commission has had the effect of awakening interest in health conditions throughout the south, so that state boards of health have become more active, and superintendents of health giving their whole time to the work have been appointed in various counties. The commission has also undertaken to obtain information in regard to the hookworm disease in foreign countries. In Europe, except in Italy, the infection is practically confined to miners, and is found in only a few well-defined localities, but in many tropical and sub-tropical countries the infection is extremely prevalent. It is said that 90 per cent. of the working population of Porto Rico are infected; on many plantations in Ceylon the infection rises as high as 90 per cent.; of the three hundred million of people in India 60 to 80 out of every hundred harbor the parasite, and conditions are nearly as bad in the southern two thirds of the Chinese Empire.

SYNTHETIC RUBBER

PROFESSOR W. H. PERKIN, of the University of Manchester, who is the son of Sir William Perkin, the discoverer of aniline dyes, presented a paper before the Society of Chemical Industry last month describing the methods by which synthetic rubber had been produced, and stating that the process is such that rubber can be made as economically as it can be obtained under natural conditions, probably, at a cost of about twenty-five cents a pound. The scientific research was undertaken under the auspices of Mr. Alfred Strange, the work being done largely by Dr. F. E. Matthews, of London, and Professor Fernbach, of the Pasteur Institute. It has been known for some time that caoutchouc, the



THE LATE RALPH STOCKMAN TARR, Professor of Physical Geography,
Cornell University.

principal constituent of india rubber, is based on a cluster of at least 10 or 20 molecules of the formula C_5H_8. It thus possesses the same composition as oil of terpentine and other terpenes, which are the chief components of fusel oils. There is a hydrocarbon called isoprene which has the formula of C_5H_8, and it has for some years been known that when this volatile liquid is allowed to stand for some time in a closed bottle, it gradually passes into a substance having the principal properties of natural caoutchouc. The same change may be effected, as Professor Harries had shown, in an article published last year, by treatment with metallic sodium. Dr. Matthews independently made the same discovery. The difficulty was that isoprene is difficult to obtain and is more expensive than india rubber. Professor Fernbach, however, after eighteen months of research, discovered a fermentation process for the production of fusel oil, one of the raw materials of isoprene, from any starchy material, such that the cost will not exceed $150 a ton.

As is well known, the existence of india rubber was learned from the Indian tribes of South America, and the best rubber known, para rubber, still comes from Brazil. In recent years plantations of rubber trees have been set out, especially in Ceylon, and about 300 tons of rubber are produced annually as compared with 70,000 tons from the wild trees. The enormous increase in the commercial demand for rubber, due to many causes but first to electrical insulation and later to the introduction of automobiles, has made the natural supply inadequate and greatly increased the cost. It may be confidently expected that the demand will further increase in the future and that rubber could be used to advantage for many purposes if it could be obtained at less expense. The discovery of the possibility of artificial rubber at a cost that competes with natural rubber is consequently an important application of modern science.

SCIENTIFIC ITEMS

WE regret to record the death of Dr. Shadworth H. Hodgson, the British philosophical author; of Dr. Ferdinand Zirkel, emeritus professor of mineralogy at Leipzig; of M. F. Lecoq du Bois-Baudran, the French chemist who discovered gallium; and of M. C. Andre, director of the Lyons Observatory.

A MEMORIAL service in honor of Robert Koch was recently held in a temple dedicated to him, which has been erected at Tokyo. The temple owes its origin to the interest of Professor Kitasato.—Lady Hooker will be grateful if any who possess letters written by her late husband, Sir Joseph Hooker, will lend them to her for the purposes of a biography which Messrs. Smith, Elder and Co. will publish.

THE nineteenth International Congress of Americanists to be held in 1914 will consist of two sessions: the first in Washington, D.. C., and the second at La Paz, Bolivia.—The International Geological Congress will hold its twelfth meeting in Canada during the summer of 1913. It is proposed to hold the meeting in Toronto beginning on or about the twenty-first day of August. —The program for the meeting of the British Association at Dundee on September 4 and following days includes garden parties at Glamis Castle, Kinfauns Castle, Rossie Priory and Camperdown and excursions to St. Andrews, Dunfermline, Arbroath and Aviemore. The president, Dr. Schäfer, of Edinburgh University, will devote his address to the developments that have taken place during the last fifty years through the study of the tissues of the body by means of the microscope. Professor Bragg will discourse on "Radiations, Old and New," and Professor Keith on "The Antiquity of Man."